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Volume 2, Number 6

AIR & SPACE
Smithsonian

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Cover: *The Swedes get their Viggens in a row in this photograph by Åke Anderson.*

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Viewport

A Global Vision

One recent evening, a business executive drove to Dulles International Airport just outside Washington, D.C., and boarded a Pan Am Airbus to France. In a Paris hotel room the following night, he watched a television broadcast of an international tennis match relayed by a satellite that had been launched by the European Space Agency aboard an Ariane rocket.

What's wrong with this story?

Absolutely nothing. The problem is that the National Air and Space Museum's displays do not reflect this degree of foreign aerospace achievement.

Recently, I took a group of Soviet science and technology leaders involved in planning last year's Washington, D.C. summit through the Museum. They were surprised to find Soviet contributions limited to a model of the original Sputnik satellite and a display of the Apollo-Soyuz docking mission. For a nation that launches close to a hundred missions into space each year—about ten times more than all other spacefaring countries combined—this lack of representation may mislead the visiting public on the degree of the Soviets' involvement in space.

Last summer, the U.S. National Academy of Engineering issued a report, *Strengthening U.S. Engineering Through International Cooperation—Some Recommendations for Action,* that critiqued America's inattention to foreign competition. Written by some of the nation's foremost engineers in industry and academia, it made these important points:

- The United States—especially its engineering and science communities—needs to adopt new attitudes and strategies if we are to maintain or enhance our industrial health and standard of living in the face of intense international economic competition.
- Although simply gaining awareness of foreign technological progress will not improve the competitive status of the United States, technological isolation will surely undermine the future of our industries and educational institutions.
- The practice and teaching of engineering in the United States must be modified to respond positively and beneficially to the growing quality and quantity of engineering activity abroad.

These points hold true for the National Air and Space Museum as well. Part of the Museum's mission should be to help show the public, especially the schoolchildren who visit the Museum, where U.S. aerospace technology has excelled and where other countries have also made significant contributions.

Currently, between one-fifth and one-quarter of the airplanes we exhibit are foreign. That may not be a bad ratio, but unfortunately, most of our foreign aircraft predate 1950. Of course, modern airplanes often have classified components, preventing public display. And many significant commercial aircraft are far too big to fit into the Museum. Nonetheless, we could be doing much better.

Similarly, among the Museum's space exhibits, only a very small fraction reflect achievements abroad. The contributions made by global weather satellites and foreign communications satellites are among the important topics we should reflect in our exhibits. Of the publicly available photographic maps of our planet's surface obtained from space, for example, those with the highest resolution are the products of foreign satellites. The Soviet Union's are the most detailed, allowing one to distinguish from orbit between a truck and a car moving along a highway. Such pictures will have immense influence as we deal with such vital issues as the spread of crop disease and the encroachment of deserts into farm- and pastureland.

I hope that in the next few years the Museum will be able to exhibit increasing numbers of foreign aerospace contributions, thereby giving our visitors a better notion of where the United States stands in this nationally vital, internationally competitive field. That sense of balance is essential if we as a country are to pursue a rational aerospace policy in the years ahead.

—Martin Harwit, Director, National Air and Space Museum

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Letters

Gone, Not Forgotten

In "The Day the Rocket Died" (October/November 1987), author Fred Reed left the impression that the Vanguard and ABMA satellite teams were in competition for the same launch facilities. This was not the case. Dedicated facilities were constructed for Project Vanguard at Complex 18, while the Army satellite launchers found themselves in competition with ballistic missile programs, including the Redstone and Jupiter projects, at Complex 26.

The Complex 18 facilities included a launch stand and gantry that were scrapped years ago, and a blockhouse, pad, and fuel storage facility that remain on the site today. But like many other landmarks of the early Space Age, Complex 18 is being allowed to crumble into oblivion.

Today Complex 26 houses the Air Force Space Museum collection of early missiles and booster rockets. The gantry tower, from which the first U.S. satellite was launched, is the collection's centerpiece, but it will be gone soon. The corrosive effects of the seaside location and years of neglect have eaten the metal away, and now the structure leans away from the prevailing east wind. The same wind sometimes blows rusted light fixtures loose from the upper levels and sends them crashing down on the concrete pad. A fence has been erected to keep visitors a safe distance away. The first issue of *Air & Space/Smithsonian* carried the news that the Air Force had been given permission to tear the gantry down.

It is sad to think that we have preserved so little of the physical facilities where the Space Age began. The gantry at Complex 5/6, where the Mercury-Redstone carried Shepard and Grissom into space, was disassembled in 1962. Marshall Space Flight Center records indicate that it was shipped to Vandenberg to support Thor-Agena operations, but I can find no indication it was ever utilized there. The scrappers have claimed the gantry at Complex 14, where the Atlas boosted U.S. astronauts into orbit. The erector-service tower of Complex 19 is crumbling badly. Even the gantries at Complexes 34 and 39, which served the Apollo missions, are gone.

In all fairness to the Air Force, these structures were never meant to last. Still, I like to visualize myself as a dignified senior citizen of the 21st century, standing in the National Air and Space Museum and listening to some kid who has traveled at hypersonic speeds in the standard aerospace transportation of the day, as he marvels at the primitive facilities that were necessary to support a mere unmanned satellite launch way back in the 1950s.

I used to wonder myself how anybody could actually fly in a biplane!
Edward C. Dempsey
Ft. Lauderdale, Florida

After Midnight

Jay P. Spenser's coverage of the life and times of Captain Midnight ("The Flight Against Evil," December 1987/January 1988) was excellent and brought back memories of radio drama, Ovaltine, and decoder badges. (I had one of those, but could that really have been 1946?) But the article only scratched the surface of the era, and I hope we can look forward to coverage of the Captain's allies in the fight against injustice. I can recall Blackhawk and his multinational squadron of stalwarts, who, like Captain Midnight, made the transition into the Jet Age. There was Sky Wolf, whose two-piece airplanes could double the odds against the evil foe, and Airboy with his jet-propelled ornithopter. Toss in Wonder Woman with her glass airplane and Baron von Emmelmann in his reincarnation as the Heap and the baddies never had a chance.
William Dahlgren
Glenview, Illinois

Symbol of Excellence

I enjoyed Diane Tedeschi's piece about *Thunder Bird,* the B-17 depicted in the Keith Ferris mural (In the Museum, December 1987/January 1988).

When I first saw this mural, I recognized the thunderbird as the one-time logo of Southwest Airways Thunderbird Field, where I took primary flight training.

I understand that this handsome bit of graphic art was designed by well-known artist Millard Sheets, who also served as architect for Thunderbird Field no. 1 (there were two) at Glendale, Arizona.

I am saddened that the original thunderbird insignias painted on the hangars have given way to thunderbirds with no graphic merit. A glance at the mural shows that the originals have borne the test of time beautifully.
Frank L. Warren
Palos Verdes Estates, California

Flying

It was a cold, overcast day during the rainy season in Lisbon, Portugal. My pilot buddies and I were discussing the attributes of assorted flying devices when someone brought up the aerodynamics capabilities of nature's winged critters—houseflies, mosquitos, and moths. How do these natural aviators perform their manuevers?

Take the housefly for example, as it flies around, turning and banking and generally pestering the daylights out of humans. Turning and banking are functions that we can relate to while not necessarily understanding. But how does the fly land on an inverted surface? Does it fly parallel to the ceiling, execute a barrel roll and grab hold (see illustration, figure a)? Or does it climb and perform a loop to grip the surface facing the opposite direction (figure b)?

When it chooses to take flight again, does the insect fly off inverted, roll out, and resume its way, or complete the remainder of its loop to reorient itself? Does it simply let go and allow its center of gravity to restore its position before it buzzes away?

Similarily, does the fly fly parallel and roll onto a landing on a vertical surface (figure c)? Or approach it head on, then flare 90 degrees (figure d)? Or perhaps approach at the moment of bank and allow the surface to meet a tangent of a turn (figure e)?

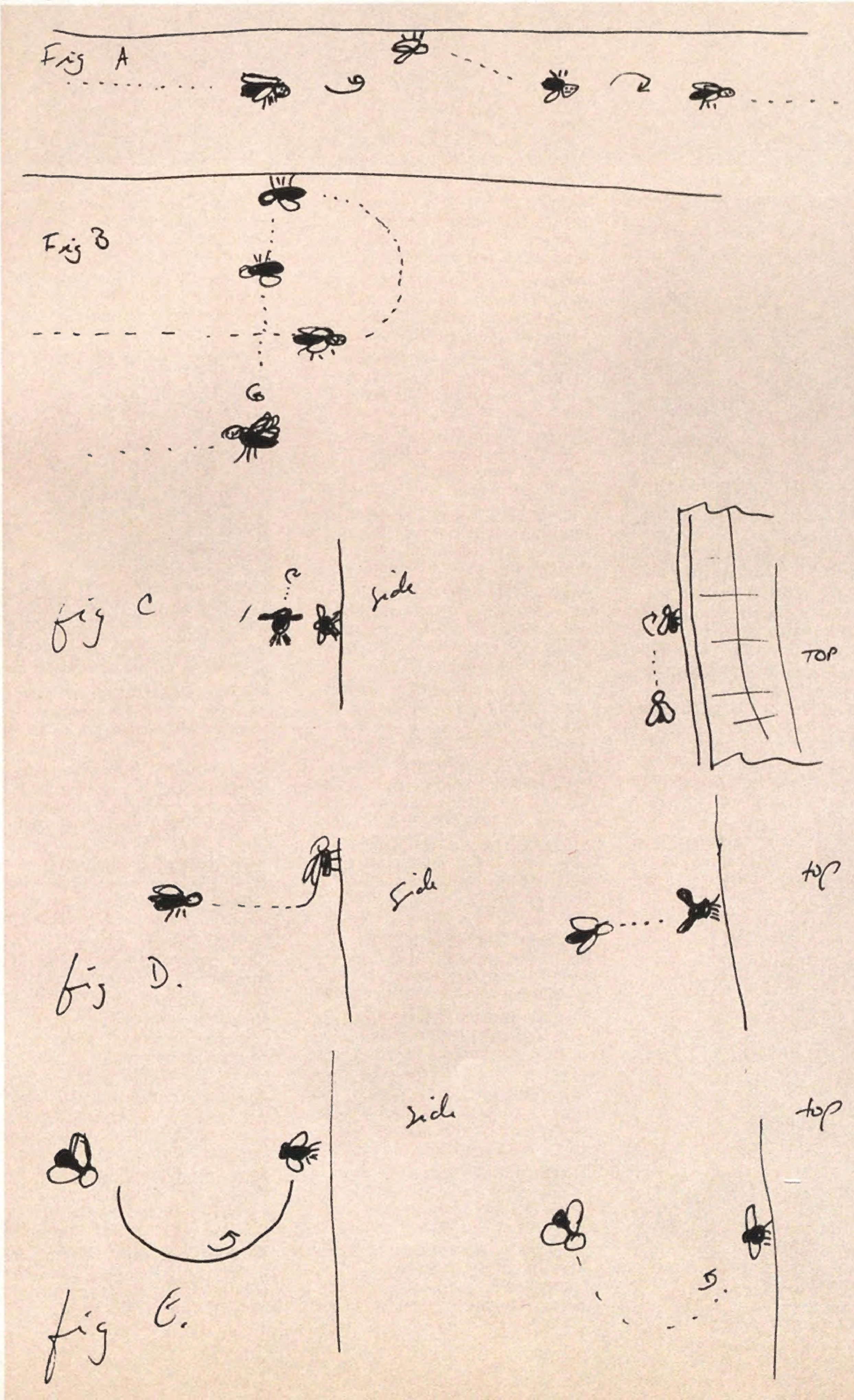
Mind you, these questions have no bearing on our next flight. They are merely the speculations of four bored pilots during a lull in activities.
John Cly
Lisbon, Portugal

Correction

In "Goin' to the Chapel of Lunch" (Soundings, December 1987/January 1988) it was reported that United Airlines donated the O'Hare Chapel's grand prize. American Airlines made the donation.

Air & Space/Smithsonian welcomes comments from its readers. Letters must be signed and may be edited for publication. Address letters to Air & Space/ Smithsonian, *National Air and Space Museum, Smithsonian Institution, Washington, DC 20560.*

John Cly



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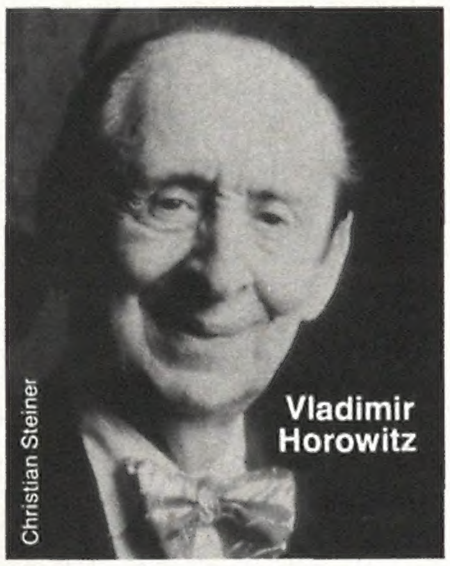

Handel, Messiah (Highlights) Musica Sacra/Westenburg. *Hallelujah Chorus, I Know That My Redeemer Liveth,* more. RCA *DIGITAL* 153586

James Galway & The Chieftains: In Ireland *Danny Boy; When You And I Were Young, Maggie; Down By The Sally Gardens;* more. RCA *DIGITAL* 124344

Ravel, Daphnis et Chloé (Complete) Montreal Symphony/Dutoit. "An absolute dream performance."—Stereo Review London *DIGITAL* 115520

Mozart, Clarinet & Oboe Concertos Pay, basset clarinet; Piguet, oboe. Academy of Ancient Music/Hogwood. L'Oiseau-Lyre *DIGITAL* 115523

Brahms, Cello Sonatas Yo-Yo Ma, cello; Emanuel Ax, piano. "Distinguished...handsomely recorded."—Stereo Review RCA *DIGITAL* 154044

Richard Stoltzman: Begin Sweet World Title song, *Amazing Grace, Clouds, Abide With Me/Blue Monk,* more. RCA *DIGITAL* 150414

Mozart, Requiem Leipzig Radio Choir; Dresden State Orchestra/Schreier. "Exceptionally satisfying."—High Fidelity Philips *DIGITAL* 115039

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Wagner, Orchestral Highlights From The Ring Vienna Philharmonic/Solti. Ride Of The Valkyries, more. London *DIGITAL* 115426

The Canadian Brass: High, Bright, Light & Clear Air On The G String, Masterpiece Theatre Theme, others. RCA *DIGITAL* 144529

Pops In Space John Williams leads The Boston Pops in music from Star Wars, Close Encounters, Superman, more. Philips *DIGITAL* 105392

Pachelbel, Canon in D Also includes other works by Pachelbel & Fasch. Maurice André, trumpet; Paillard Chamber Orchestra. RCA 133877

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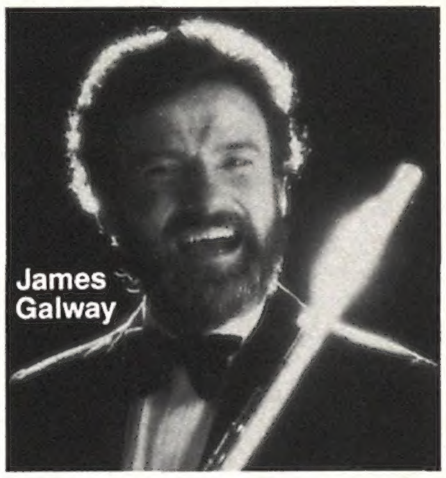
Sousa, Stars & Stripes Forever Philip Jones Ensemble. Plus *Semper Fidelis, Washington Post,* more. London *DIGITAL* 115051



Michael Feinstein: Remember Irving Berlin standards include title song, *Alexander's Ragtime Band, Puttin' On The Ritz,* more. Elektra 153947

Tchaikovsky, Symphony No. 6 (Pathétique) Chicago Symphony Orchestra/Levine. "A sound that dazzles and sings."—Milwaukee Journal RCA *DIGITAL* 153939

Teresa Stratas Sings Kurt Weill *Havanna-Lied, Foolish Heart, Lonely House, Surabaya-Johnny, One Life To Live,* more. Nonesuch 124748

Rudolf Serkin: Mozart, Piano Concertos Nos. 12 & 20 "He makes every phrase glow with life."—Stereo Review DG *DIGITAL* 115062

Rossini, Overtures Orpheus Chamber Orchestra. The Barber Of Seville, The Turk In Italy, Tancredi, 5 others. DG *DIGITAL* 115527

Gregorian Chant Schola of the Hofburgkapelle, Vienna. 10 Propers from Graduale Romanum; more. Philips *DIGITAL* 115434

Alicia de Larrocha: Falla, Nights In The Gardens Of Spain Plus rhapsodies by Albéniz & Turina. London *DIGITAL* 115410

Tomita: The Mind Of The Universe (Live At Linz, 1984) Ode To Joy, Also Sprach Zarathustra (opening), more. RCA 173829

Up for Adoption

"Franklin Institute, can I help you?"

"Hi, I'm calling from *Air & Space* about the 707 you're giving away."

"Oh, how nice. Do you want it?" the voice asked hopefully.

The Philadelphia museum was having a hard time giving away its Boeing 707 airliner, which was taking up space targeted for new buildings and an Omniverse theater. Of course, there's no such thing as a free lunch: whoever took the exhibit had to come up with $100,000—give or take a few thousand depending on location—to disassemble it and move it to its new site.

Museum officials don't want to give their blue and white 707 to just *any*body. "It's part of the Institute family," says John McDevitt, director of operations. "Besides, we're the only one on the block with a 707. We want to find it a good home."

After landing at Philadelphia International in 1975, the Boeing donation had its wings and engines removed. It made a stately procession via truck bed down I-75 and up Broad Street, stopping for photographs at City Hall. Once in place at the institute's Science Park, it was hoisted onto a pedestal, where the wings and fuselage were re-mated. Since then, Foxtrot Papa—"our 66-ton monster," as one museum employee calls it—has rested on pilings in the midst of museum buildings, where visitors can wander through it.

McDevitt's main concern is that the 707 not be scrapped or even disfigured. "Someone wanted to turn it into a restaurant, but we're, um, not interested in that," he says. "We'd love to keep it in the Philadelphia area as an exhibit or an educational device."

Queries have come from the Asian Museum of Aviation in Beijing; the Port Authority of New York and New Jersey, which wants it as a ground crew training aid at Kennedy Airport; and the town of Danby, Vermont. "We also got a letter from the county of Chester, Pennsylvania, which wants it for disaster training." McDevitt, a man faced with a hard choice, heaved a sigh. "I guess that's a worthy enough cause."

Danby—population 1,008—hopes Foxtrot Papa will put it on the map. "I wasn't *looking* for an airplane," says Allen Wilcox, organizer of the drive. "But I read about it in the Rutland *Herald* and got to thinking about what an attention-getter it would be—a reason for people from the ski areas to come down here." Wilcox even has the move all figured out. "We'll bring it up the canal system after lowering it off a bridge onto a barge." If tickets were sold to that event alone, the proceeds would probably finance the entire project.

—*Patricia Trenner*

Illustrations by Steve McCracken

Brighton Beach Seminars

In a blaze of lights for the TV cameras, the 38th congress of the International Astronautical Federation commenced last October in Brighton, England, just days after Margaret Thatcher's cabinet rejected a request from the British National Space Centre to triple its annual budget. As IAF delegates streamed into the south coast city, Alan Bond, one of the nation's most promising aerospace engineers, announced that if his government would not dole out another shilling for space technology he would peddle his expertise abroad.

Bond invented the propulsion technology for the HOTOL—a British spacecraft that would take off and land like an airplane. But by refusing to increase its contribution to the European Space Agency, Great Britain nixes its chance of selling the $7 billion HOTOL to the agency, which is anxious to establish a European manned presence in space.

HOTOL's competitors are France's Hermes and West Germany's Sänger spaceplanes. At the congress, delegates suggested that the Hermes design may have serious flaws but that HOTOL and Sänger were worth pursuing.

The Soviets were lavished with praise for 30 years of accomplishments in space and their plans for the next 30. Boris Raushenbach of Moscow's Interkosmos Council talked about a large add-on complex—the equivalent of several Mir-size space stations fitted together like Tinker Toys—that will service swarms of autonomous spacecraft.

Cosmonaut Valery Ryumin, who has logged 361 days in space, reported that manned missions of more than a year will prepare cosmonauts for the inevitable Mars mission. Squelching persistent rumors, planetary scientist Valery Barsukov said the Soviets will not send cosmonauts to Mars in this century but rather a series of robotic missions, including one that would return soil samples.

European delegates repeatedly pointed to the Soviet Union and the United States as stellar examples of commitment to space exploration. Comparing the meager budgets for their space programs to the billions NASA receives, they chose not to acknowledge that while per-capita space spending is indeed higher in the U.S., NASA shares the Europeans' dilemma: grand dreams but insufficient funds.

NASA administrator James Fletcher chose not to talk about the agency's problems, nor its shuttle, nor its proposed space station—of all things, he singled out the search for extraterrestrial intelligence as NASA's most important endeavor in the next 30 years. He also predicted that in 2017 the world will receive news of the first baby born on the moon.

The worst storm to hit England in 200 years provided a thrilling finale to the congress. As windows smashed and roof tiles blew away, delegates spent the last day discussing the week's fact and fiction over pints of bitter and hoping that next year's congress in Bangalore, India, would not coincide with the monsoon season.

—Linda Billings

Loaded for Bear

Ed's Innoko River Lodge sits on a remote 40 acres 250 miles northwest of Anchorage, Alaska. Like many rural Alaskans, owner Ed Gurtler relies on his airplane—a 1952 Cessna 170—to get around.

One day last October, Gurtler packed up to fly home to Wasilla, near Anchorage, after spending a month at the lodge. "I had about 550 pounds of moose meat in the Cessna, all cleaned and boned and ready to go," he says. About 2 a.m. Gurtler heard what he figured was the wind "bouncing the tail up and down." He got out of bed to investigate and found a grizzly bear picking up the Cessna and slamming it to the ground.

"He'd just gotten through breaking the airplane in half when I came out," Gurtler says. "I fired a shot from my .357 Magnum over his head, but that didn't drive him away. So I figured I'd better let him have the plane, and I went back inside."

At daybreak, Gurtler assessed the damage. "He picked out the seats, chewed on them, and ate or took about 350 pounds of meat. Looked like he punched out the back window, climbed in, and punched the doors out. No problem for him—judging from his tracks, I figure he was nine feet tall and weighed a thousand pounds."

Gurtler, however, does have a problem—the Cessna was uninsured, and repairing it "is beyond my reach, financially." So the bloodied and broken silver 170 sits at the lodge, which is closed until Gurtler can either buy another airplane or piece the Cessna back together. "I'm looking for a job," he says.

"It was probably the first time Ed packed meat into the plane the night before taking off," says Charley Beatty, the state trooper who flew Gurtler home after he radioed for help. "Most people wait until just before they leave. I doubt he'll make that mistake again."

—Michael Rozek

A Jug of Wine, a Loaf of Bread, and Wally Schirra

Every Wednesday during the school year, a couple of dozen space enthusiasts meet at the California Space Institute's Brown Bag Lunch Seminar. Over the sounds of crashing surf, crunching apples, and rustling sandwich wrappers, they listen intently to the guest speaker and then join in spirited discussions.

The speakers are scientists, engineers, and government and aerospace industry representatives, as well as the occasional psychologist, anthropologist, and philosopher. The dialogue is casual but unrelentingly inquisitive, with equal time given to undergraduates and Nobel Prize winners.

"We encourage open discussion and don't have to be quite as 'respectable' as more formal groups," says James Arnold, the affable founder and director of the California Space Institute, a San Diego-based research division of the University of California. "Our hope is to build a community of people with a common interest in space, and the seminars provide an open forum for technical and social issues relating to our future in it. We talk about things we can do to make access to space easier, cheaper, and quicker." Arnold's interdisciplinary approach has given rise to topics ranging from "Green Thumb Methods of Inference" to "Polynesian Metaphors of Space Exploration."

One of the best attended was October 28th's "Our Goals in Space." Former astronaut Wally Schirra, who has a background in engineering, gave a compelling presentation on where the United States should be heading. He called for greater emphasis on the space station, which he says could be used to study the effects of space habitation on humans before more grandiose projects, such as a

manned Mars mission, are undertaken.

In a lighter moment, Schirra recalled the 10 days he spent orbiting Earth in the 1968 Apollo 7 mission: "I'll tell you, when you can't eat out, after a few days even brown-bagging it is no fun."

—*Sean Henahan*

Wrather Port Properties, Ltd.

Long Beach, Short Flight

The press called it the Spruce Goose, "but you didn't call her that around Howard Hughes," says Chuck Jucker, the crew chief who was on board for the airplane's only flight. "That was Senator Brewster's name for her, and Mr. Hughes didn't think much of him, either."

Forty years after Howard Hughes got his Flying Boat, as he preferred to call it, aloft for one minute, 12 crew and management team members gathered in the dome housing the birch behemoth to sign autographs and regale tourists with stories about the airplane and its eccentric creator.

In 1947, Senator Owen Brewster was marshalling an inquiry into Hughes Aircraft Company's "flying lumberyard," the H-4 Hercules, which had cost the government $18 million and was already three years behind schedule. After an appearance before a Senate investigation committee in Washington, Hughes returned to California and on November 2 guided the Hercules into Long Beach Harbor to "preview the airplane" before hearings resumed.

"He was in a good mood that day," says copilot Dave Grant. "Even before the taxi tests began we all figured he'd take her up." After the second run, reporters aboard asked Hughes if he intended to fly today. Most got off to file their stories when Hughes said no.

"He spent a good half-hour on the radio getting the press boat moved around for pictures," Grant says. Then Hughes made his move. "He called for 15 degrees of flap—takeoff position."

Hughes let the speed build up to about 70 mph and gently coaxed the Hercules aloft on its third run. The reporters were astonished, but not the crew. "It behaved beautifully," Grant says.

The flight was brief, says Jucker, because there wasn't much fuel in the tanks. "There was no safety equipment, like life jackets, but she would have floated just fine with all that wood."

The crew had no reason to believe the one-mile flight would be the last. Over the next few years Hughes ordered a string of safety improvements: a battery-powered backup hydraulic system, emergency fresh-air ducts for the pilot, fire extinguishers. "He had a phobia about fire," Jucker says. "It seemed to start right after his XF-11 crashed and burned the year before."

The H-4 was kept in various stages of airworthiness for another 30 years, but it never flew again. "I guess he was busy with his movies and his troubles with the government," says Grant. "He wouldn't let anyone else fly her—said he wasn't going to pay someone else to have all the fun. When he moved to Las Vegas in the '60s, the change orders stopped."

But there may be another chapter in the saga. Officials in Nagoya, Japan, want to borrow the H-4 for the Expo '89 design convention. Wrather Port Properties, the aircraft's caretaker, is doing a feasibility and cost study on disassembly and overseas transportation: a ballpark estimate for the cost of the move is about $10 million.

Grant worries that all the king's horses and men might have a hard time reassembling Hughes' masterpiece. He suggests lifting it onto a supertanker and shipping it in one piece instead. "But you know, they've taken good care of her over the years. Maybe it would be cheaper to just fly her over."

—*Mike Blakemore*

GM's 2,000-Mile Recruitment Drive

Last November an $8 million General Motors car called the GM-Hughes Sunraycer won a 1,950-mile race in Australia—fueled only by the sun. Even with GM's well-oiled publicity machine running at full power, it's doubtful many people cared. But it's a safe bet that those who did were young and technically oriented.

Joel Rieman

Which was exactly the point, according to GM president Robert C. Stempel. More than a show of technological prowess, GM's participation in the race served as a recruiting drive for tomorrow's engineers—engineers that U.S. executives fear we are not going to have unless we spark a few imaginations.

The Pentax World Solar Challenge was run on Australia's Stuart Highway, a rough asphalt ribbon stretching from Darwin, on the continent's "Top End," south through the desert to Adelaide. Each entry had to weigh less than 800 pounds, be powered exclusively by the sun through a solar array, and have reasonable handling and braking performance.

The GM-Hughes solution, dubbed the Flying Cockroach, evolved in only seven months. One of project manager Howard Wilson's first moves was to recruit Paul MacCready and the staff of AeroVironment, Inc., in Monrovia, California, renowned for their success in human- and solar-powered vehicles like the *Gossamer Albatross* and *Solar Challenger.*

AeroVironment was charged with designing the basic vehicle. MacCready used all the weapons at his disposal to minimize drag, including a NASA-derived computer program and CalTech and GM wind tunnels. The result was an aluminum-tube frame supporting a Kevlar-Nomex composite body that weighed 360 pounds but was stable enough to withstand sidelong gusts created by triple-trailer trucks plying the Stuart Highway at 80 mph. Hughes Aircraft contributed 7,200 solar cells—the same type used on its communications satellites—which produced around 1,000 watts of power at 150 volts, about what a hair drier uses.

Wilson says the Sunraycer's top speed under solar power alone is 48 mph; aided by battery power it can top 60. Six drivers spelled one another during each day's 8 a.m.-to-5 p.m. race in temperatures up to 110 degrees Fahrenheit.

When the checkered flag ended the five-day race, the Sunraycer had beaten 24 entries from seven nations, leaving its nearest rival 600 miles behind. It finished in just under 43 hours at an average speed of 43.5 mph, encountering nothing worse than three flat tires.

The success of GM's recruiting drive remains to be seen. To reinforce its point, Chevrolet plans to take the Sunraycer to

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Galaxy II and INTELSAT satellites are now transmitting U.S. television programming to Japan using a hookup provided by Hughes Aircraft Company. NHK, Japan's leading television broadcaster, transmits from its New York studio to Hughes' Brooklyn, New York ground station. The signal is sent to Hughes' Filmore, California ground station via Galaxy II, and then beamed to an INTELSAT satellite over the Pacific Ocean. The signal is then relayed to a Japanese ground station north of Tokyo and fed into the local NHK studio. The daily broadcasts include segments of major U.S. and European news and entertainment programs, plus live on-the-scene reports from NHK bureaus in North America and Europe. Galaxy II is one of three domestic satellites owned and operated by Hughes Communications, Inc., a subsidiary of Hughes.

Hughes is reducing software costs to customers by up to 40 percent via the comprehensive Hughes Software Engineering Environment ($SE^{2®}$). SE^2 is an integrated system of computers, workstations, communications, specialized software tools, and comprehensive training and user support. The system lets engineers and managers focus their efforts on software development, quality, and productivity, without having to supervise a complex computer facility. Operating successfully for several years on many diverse domestic and international real-time, computer-controlled projects, SE^2 provides a complete life cycle of software development and support. Hughes is continually updating SE^2, including a 1986 upgrade to comprise a total Ada® capability.

A new graphics projector offers improved performance for the large-screen display of computer data. Designed and built by Hughes, the Model 800 graphics projector increases brightness to more than 600 lumens and improves resolution to over 1,000 lines edge to edge. The projector combines high-intensity illumination with Hughes' liquid crystal light valve technology to generate bright, real-time projected displays of both graphic and alphanumeric images in normal room light. The Model 800 is designed for applications including computer-assisted training, design conferences, sales presentations, teleconferencing, and classroom and lecture hall use.

A system for night reconnaissance, border surveillance, and specialized military applications has recently completed 150 successful cross-country demonstration flights. The approach utilizes a Hughes Night Vision System (HNVS) aboard Schweizer Aircraft Corporation's new SA 2-37A Special Purpose Aircraft. The HNVS is a forward-looking infrared (FLIR) system that lets crew members see at night and in poor visibility conditions. Unlike radar, the FLIR emits no energy of its own that can be detected during operations. It can locate and track vehicles and, at its maximum magnification setting, can even delineate individual tree limbs and branches. HNVS is in use by the U.S. Army and the U.S. Customs Service, and was selected for use on the proposed V-22 Osprey tilt-rotor aircraft.

Hughes Missile Systems Group is advancing every phase of research and development, as it applies to tactical guided missile systems and strategic defense. Opportunities for engineers and scientists are in analog/digital circuit design; high-voltage power supply design; transmitter and radome design; electro-optical design; IR imaging sensors; focal plane arrays; mechanical engineering; and systems engineering. Send resume to Hughes Engineering Employment, Dept. S4, 8433 Fallbrook Ave., Canoga Park, CA 91304. Equal opportunity employer. U.S. citizenship required.

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For more information write to: P.O. Box 45068, Los Angeles, CA 90045-0068

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500 schools. Winning the World Solar Challenge might be the easiest part of the battle in a society that pays its lawyers far more than its engineers and scientists.

—*Steven L. Thompson*

Pomp and Circumstances

Last October the Federal Aviation Administration held a ceremony at its Air Route Traffic Control Center (ARTCC) in Leesburg, Virginia, to dedicate the center's new IBM computer, which serves as host for the software that has run the air traffic control system for 20 years. The FAA wanted to keep its proven software but run it on a faster, more reliable computer. Radar information is sent to these ARTCC computers, which generate symbols on electronic displays monitored by controllers who track aircraft in the en route phase of a flight. Installation of the new computer system is one of the first steps in a $12 billion updating of the air traffic control system. Leesburg is the fifth center to receive the new IBMs; eventually all 20 ARTCCs in the continental United States will have them.

During a tour of the computer room, the man from IBM explained that the new computer can do many times the work of the old one, which was so antiquated that it relied on mechanical devices like punch-card readers. He paused to let this sink in.

Dozens of retired controllers, a number of former FAA administrators, and one state police officer in full regalia were in attendance for the dedication. After a color guard placed flags on the platform, there were brief speeches from various officials, including the mayor, who said how glad Leesburg was to have the center.

FAA administrator T. Allen McArtor explained that the agency had mulled over ideas on how to proclaim the updated system up and running. They decided to choose a flight scheduled to pass through Leesburg's airspace during the ceremony and designate it the first to be officially managed by the new computer. (The IBM man had said earlier that the new computer had already been managing traffic for days, but ceremony makes certain demands on history.) The image that appeared on the controller's radarscope would also appear on a large video display screen so the audience at the ceremony could follow the flight through the system.

Before McArtor spoke, dignitaries on the platform passed notes back and forth, and Leesburg ARTCC manager Chuck Reavis smoothly interjected a few off-the-cuff remarks into the proceedings. Actually, he was buying time. The FAA had listed three flights that were to enter Leesburg's airspace during the ceremony, and the captains of each had been told that any one of them could expect a call from McArtor at the appropriate moment. The moment was fast approaching—but not the airliners. So Reavis ad-libbed for a few minutes, and in the nick of time United 607, blissfully unaware of the ceremony, sailed into Leesburg's airspace. The video display picked up a blip marked UA607 moving smartly across the radarscope. According to a chief pilot at United who later checked into the matter, the captain of UA607 had only a sketchy idea of what was to come.

McArtor keyed a radio handset, identified himself, and asked for Captain Smith (not his real name, and the airline won't reveal it). He advised Smith that his was the first flight to be handled by the new computer. There was a two-second pause—one can only imagine what went through Smith's mind. But resisting the temptation to reply "C'mon, who is this *really?*"—or worse—Smith picked up the beat, thanked the administrator and controllers everywhere, proclaimed the skies safe, and wished the FAA health and long life. As McArtor terminated the call with a crisp "Washington out," the screen went dark, the colors were withdrawn from the platform, and the ceremony ended. The chief pilot says United is sending its man Smith a letter of commendation.

—*George C. Larson*

Unhappy Landings

Nothing looks quite so cheerful as a hot-air balloon wafting over a country landscape. But for some farmers these seemingly innocent nylon bubbles are vehicles of destruction. According to the New Jersey Farm Bureau, balloons have ruined fields, upset livestock, and contributed to the death of a $50,000 racehorse.

Last year, backed by the bureau, Senator Wayne Dumont introduced legislation that would raise state fines for landing on private property—except in emergencies—from $100 to as much as $1,500. Balloonists, who rely on open fields for safe landings, are outraged. In most cases, they say, a balloon landing ends up delighting rather than distressing a landowner. "If I'm on a farmer's property I can be either his guest or his trespasser," says Rich Metowski, who soothes irritated farmers with on-the-spot rides. "I do everything I can to avoid offending them." Balloonists say existing laws and insurance cover damages, and fear that the threat of fines will force them to land on hazardous terrain. Besides, they argue, who will determine what constitutes an emergency: the farmer, the balloonist, or the FAA?

Last August the state senate passed the bill, which has since languished in the state assembly's transportation committee. Opponents are betting it will never get the nod from the full assembly, and some legislators are pronouncing it already dead.

Nothing would please Malcolm Forbes more. "New Jersey would be the first and only state to do away with the sport," says the mega-millionaire publisher and avid balloonist. "I suppose *I* could afford to land a few times, but few others could." Assemblyman John Penn, a representative of Forbes' district and a member of the transportation committee, sides with his constituent. "If they do it for balloons, the next thing you know they'll do it for gliders," says the glider pilot.

But a zealous Dumont says if his bill fails to pass he'll simply reintroduce it. "We have to do all we can to preserve agriculture in this state," he declares. "These balloons on farmers' land can destroy their fields and their income. I don't see why a hobby is as important as feeding people."

Whatever the bill's fate, it has put balloonists on alert. Forbes predicts they will be on their best behavior from now on. "The bill has heightened awareness and should minimize the incidents," he says. "It's accomplished something."

—*Patricia Herold*

Joyriding

Necessity may be the mother of invention, but John Sassak's Saker Space Probe ride owes more to a department store display. A

Ping-Pong ball hovering on a column of air caught Sassak's attention one day in the late 1970s. Fascinated, he wondered what it would be like to ride inside the orb.

To find out, Sassak built a prototype ride and named it the Saker Space Probe (a saker is a European falcon). It consists of a large fiberglass ball to hold the rider, a base shaped like an egg cup to support the ball, and an eight-foot plexiglass cylinder to hold both base and ball. Three 15-horsepower engines inside the base turn a propeller, which creates a blast of air that boosts the ball to the top of the cylinder. There the pilot controls the ball with a wheel—fins on the outside function like rudders, while shifting weights control roll and yaw. "It's real seat-of-the-pants flying," Sassak says. Video monitors simulate scenes such as a carrier landing, and the pilot can fire at photosensor targets, the video-game effect heightened by sound effects.

Sassak, who has a degree in aeronautics and has owned a string of airplanes and helicopters, has long been interested in things mechanical. He was director of product development at Ford for 19 years, leaving in 1958 to start an automotive tooling business in Livonia, Michigan. When

Maureen Tierney/Stansbury, Ronsaville, Wood Inc.

the U.S. auto market went soft, he bought a couple of taverns and ventured into electronics—including video games.

In 1982 Sassak put a mechanical bull at one of his bars out to pasture and replaced it with a Saker. Drunks would bluster into the Space Probe, spin it upside down, and emerge limply sober after their two-minute ride. But pilots, Sassak says, "would immediately do acrobatics—they'd just go berserk," sometimes betting on how many times they could spin the ball.

Sassak demonstrated the Saker to Bell Helicopter in 1983, promoting its flight simulator capabilities. "But we didn't have all the answers then," he says. "Everyone blew holes in it." So Sassak decided to peddle the Space Probe as an amusement ride.

It was a profitable move. Sakers in 8-, 15-, and 30-foot versions are now at 15 amusement parks and space camps in Europe, Japan, and the United States, including the Alabama Space and Rocket Center in Huntsville. And last year the Space Probe won the Major Amusement Ride award at the International Amusement Convention in Orlando, Florida.

But Sassak still hopes his ride will find a real job. Plans for NASA to take it to last June's Paris airshow fell through. "We wanted to demonstrate the simulator possibilities," Sassak says. "I believe that with the proper instrumentation, a person could spend four or five hours in a Saker, and then take off and land a plane or helicopter."

Sassak wants to resume talks with Bell, but first he hopes to build a 75-foot Triple Tower Space Probe for 18 riders. He also plans a Saker Space Station, which will incorporate the Probe into a 50-player Galactic Battlefield game.

Show biz beckons as well. Sassak says that a movie featuring the Saker is in the works, and that producers of the David Letterman show want to arrange a televised flight—as soon as they figure out how to get the 15-foot tube in the studio elevator.

—Thomas Bedell

Update

American Rocket Company ("The California Rocket Race," December 1987/January 1988), caught in last October's stock market crunch, laid off nearly half its employees after several key investors were forced to withdraw financial backing. AMROC executives, who have weathered similar storms, are confident the cash flow problem will cause only minor delays in suborbital testing.

A high-resolution satellite imaging capability geared to media customers ("Mark Brender, Reporting from Space," October/November 1987) will be introduced by the Earth Observation Satellite Company in 1994. Current SPOT imagery provides 10-meter (33-foot) resolution; EOSAT's Star sensor will provide twice the detail. EOSAT officials expect the license application for Star to be challenged by the U.S. Department of Commerce as a threat to national security.

Tornadoes may be responsible for dark streaks across Mars' southern hemisphere ("Putting Mars on the Map," October/November 1987). Brown University researchers, studying Mariner 9 and Viking photos, noted that lines up to 80 miles long, cutting across crater walls and canyons, reappear in a different pattern at the end of each Martian summer. They concluded that the planet's turbulent atmosphere annually spawns thousands of tornadoes more violent than the Earthly sort.

In an effort to prevent space debris accumulation, the Department of Defense will build satellites better equipped to withstand the rigors of orbit ("Eyes on the Sky," April/May 1987). DOD is also attempting to involve spacefaring nations in establishing international policy on controlling space junk.

The organizer of the Eiffel Tower in space competition (Groundling's Notebook, June/July 1987) is soliciting opinions on the merit of orbital art. Phillippe Gillieron notes that the hue and cry against art in orbit is similar to that raised in Paris when Gustave Eiffel announced in 1887 that he would build a work of art that would tower over the city. The newspaper *Le Temps* published protests from "passionate lovers of the beauty of Paris" who claimed that the tower would cause tourists to cry out in astonishment, "What is this horror the French have found to give us an idea of their so highly cracked-up good taste?" Write to Gillieron at Free Comment, 13 rue de Beethoven, 75016 Paris, France.

High-G-force exposure ("High Gs, High Risk," October/November 1987) may contribute to an increase in the female population. Bertis Little, a professor of obstetrics at the University of Texas, has completed a study showing that fighter pilots and astronauts produce 10 percent fewer sons than do transport and bomber pilots. Little is continuing his research by subjecting mice to high Gs in a centrifuge and studying their sperm cells.

—Patricia Trenner

Anniversaries . . .

1888
March 12 The Great Blizzard of '88 begins in the northeastern United States. In Washington, D.C., communications were cut off before cities to the north could be warned of the storm's severity. As a result, half of the 400 deaths caused by the blizzard occurred in New York City, where winds whipped up snowdrifts that reached the elevated railroad tracks.

1914
February 28 The Steamboat Inspection Service of the U.S. Department of Commerce issues its first aircraft operator's license, enabling one Henry Waite to carry paying passengers. On the certificate, the service simply crossed out "vessels" and typed in "aeroplanes."

A few keystrokes changed a steamboat license into an "aeroplane" license.

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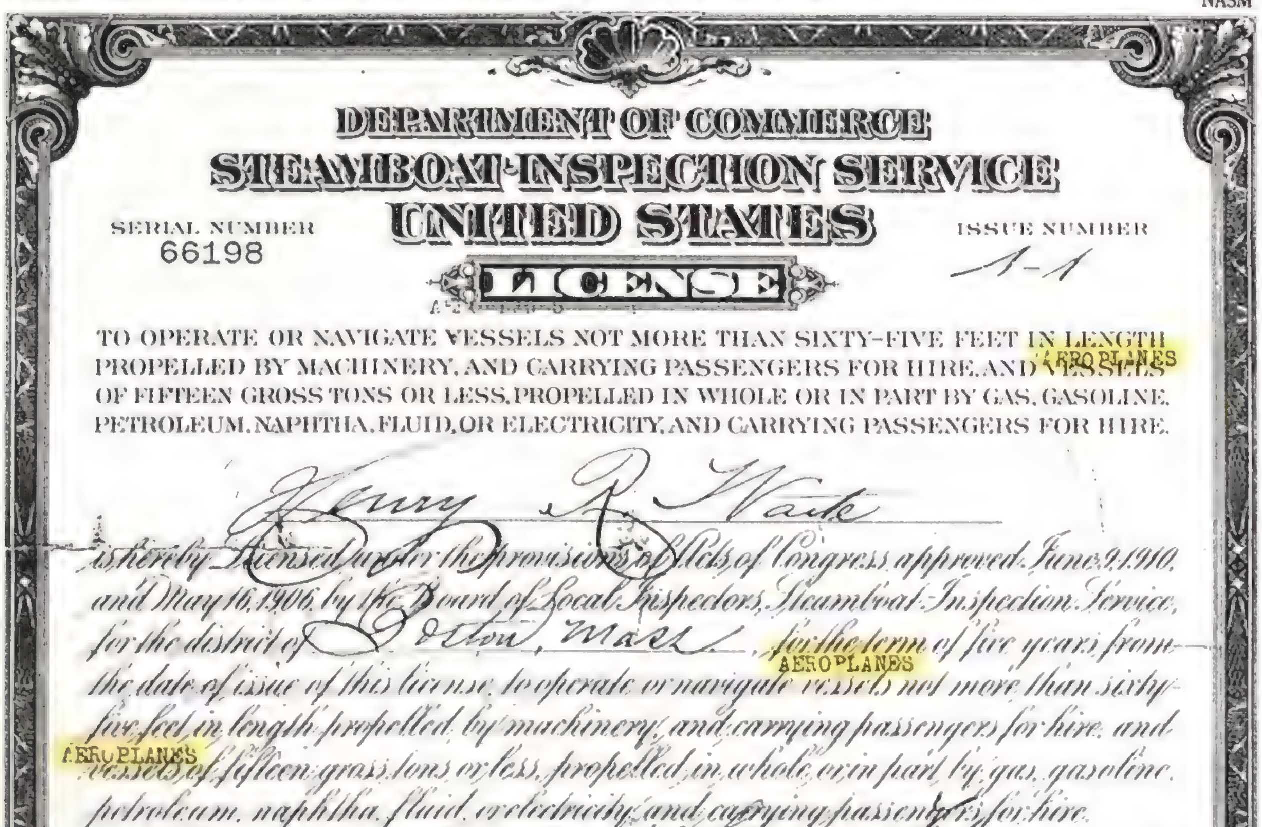
DEPARTMENT OF COMMERCE
STEAMBOAT INSPECTION SERVICE
UNITED STATES

SERIAL NUMBER 66198

ISSUE NUMBER 1-1

LICENSE

TO OPERATE OR NAVIGATE ~~VESSELS~~ AEROPLANES NOT MORE THAN SIXTY-FIVE FEET IN LENGTH PROPELLED BY MACHINERY, AND CARRYING PASSENGERS FOR HIRE, AND ~~VESSELS~~ AEROPLANES OF FIFTEEN GROSS TONS OR LESS, PROPELLED IN WHOLE OR IN PART BY GAS, GASOLINE, PETROLEUM, NAPHTHA, FLUID, OR ELECTRICITY, AND CARRYING PASSENGERS FOR HIRE.

Henry R. Waite

is hereby licensed under the provisions of Acts of Congress approved June 9, 1910, and May 16, 1906, by the Board of Local Inspectors, Steamboat Inspection Service, for the district of ______, Mass, for the term of five years from the date of issue of this license, to operate or navigate ~~vessels~~ AEROPLANES not more than sixty-five feet in length propelled by machinery, and carrying passengers for hire, and ~~vessels~~ AEROPLANES of fifteen gross tons or less, propelled in whole or in part by gas, gasoline, petroleum, naphtha, fluid, or electricity, and carrying passengers for hire.

Given under our hands this 28th day of February, 1914.

U.S. Local Inspector of Hulls

U.S. Local Inspector of Boilers

1915
March 3 The National Advisory Committee for Aeronautics is established. The committee consisted of representatives from the War and Navy Departments, the Weather Bureau, the Bureau of Standards, the Smithsonian Institution, and others "acquainted with the needs of aeronautical science or skilled in aeronautical engineering." NACA was absorbed by NASA in 1958.

1919
February 27 The first performance of Gustav Holst's orchestral suite *The Planets* is given in London. Holst, who confessed that casting horoscopes was his "pet vice," said astrological theories inspired his composition.

1922
March 20 The Navy commissions its first aircraft carrier, the USS *Langley*, in Norfolk, Virginia. The bugle call "Boots and Saddles," which signaled cavalry soldiers to mount their horses, was used to call pilots to their aircraft. After training hundreds of Naval aviators in carrier operations, its flight deck was cut in half and the ship was converted to a seaplane tender. During World War II it was crammed full of Curtiss P-40 fighters and sent off to assist Dutch forces defending Java from Japanese attack. But according to a Naval history document, "the *Langley* was still only a glorified collier, slow and poky. She could not keep up with the fleet—she was always in the way or holding up maneuvers." The *Langley* was put out of its antiquated misery by enemy bombers and sank with its load of Warhawks at Java on February 27, 1942.

1924
March 5 "At this time of the year the Platte River assumes an ugly, hostile attitude," wrote Major Lawrence Churchill in the *Air Service News Letter.* In his article, entitled "Battle of the Platte River," Churchill describes how Army Air Service de Havilland DH-4s and Martin bombers spent several hours dropping bombs on ice jams from 1,000 feet to prevent the river from flooding North Bend, Nebraska, in 1924. "The attack caused complete capitulation of the enemy," Churchill wrote. "Due to the Air Service, the Union Pacific was able to run trains over its main line by 4 a.m."

1928
February 22 Bert Hinkler lands at Darwin, completing the first solo flight from England to Australia. The 12,000-mile trip took 15 days, nearly half the time of previous flights. Hinkler, a former test pilot, triggered a national mania similar to the Lindbergh fever that swept the United States the previous spring: Australian citizens danced the Hinkler Quickstep and chefs created dishes such as Consommé à l'Hinkler. In Australia's official tribute, the

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Bert Hinkler's helmet inspired a cloche hat worn by fashionable Australians.

government claimed that Hinkler's flight "was not a stunt or freak flight; it has reestablished Australia in the eyes of the world."

1937

February 21 Yet another attempt to market an automobile-airplane combination commences with the first flight of the Waterman Arrowbile. Advertised as a "master of the skyways and highways," the Arrowbile cruised aloft at 100 mph. To keep production costs down, the aircraft was made with numerous stock Studebaker parts, including the six-cylinder engine. The Arrowbile was a hit at auto shows but not with airplane buyers.

The Arrowbile had a face that only a Studebaker owner could love.

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1948

March 10 Herbert Henry Hoover becomes the first civilian to exceed the speed of sound. The chief test pilot of the National Advisory Committee for Aeronautics flew the second Bell XS-1 six months after Chuck Yeager achieved Mach 1.06 in the first. After reaching the same speed, Hoover coasted to a dry lake bed for landing but could not extend the nosegear. He touched down, held the nose off as long as possible, and skidded to a stop that resulted in only slight damage. The XS-1 was flying again within 10 days.

Northrop

John Stapp starred in a program that repeatedly came to a screeching halt.

1954

March 19 Lieutenant Colonel John Paul Stapp, U.S. Air Force, tests Northrop Aircraft's "abrupt deceleration vehicle" at Alamogordo, New Mexico (see "Mr. G," October/November 1987, p. 72). The rocket-driven sled, designed to test the effects of high-speed, high-altitude bailouts on pilots, attained 421 mph on its first run. In a later trial, Stapp reached 632 mph.

1962

March 21 The Air Force ejects a bear in a capsule from a B-58 at 35,000 feet and 870 mph during a study of ejection from supersonic aircraft. The bear landed safely after an eight-minute parachute ride.

1964

February 3 The Federal Aviation Administration launches a six-month test of public reaction to sonic booms in Oklahoma City as part of a study to develop a supersonic transport. Air Force F-104s made Mach 1.5 runs at 30,000 feet over the city eight times a day, resulting in thousands of calls to—and claims against—the FAA. They ranged from reports of structural damage to a death threat against agency administrator Najeeb Halaby, as well as complaints about shrinking furniture, a brassiere strap that snapped with each boom, and a family of skunks under a general store who, eight times a day, "retaliated in the only way they knew how."

"I remember those booms," says an Oklahoma City Historical Society researcher. "We thought they were the reason all our chicken eggs cracked. Then again, maybe they just had weak shells."

1966

March 17 The Bell Aerosystems Company ducted-fan tilt-rotor X-22A aircraft makes its first flight, at Niagara Falls International Airport. It was severely damaged several months later by a hard landing made after a hydraulic system failure. The ducted-fan design was abandoned in favor of the cleaner lines of the XV-15, which debuted in 1977 and has enjoyed a large military following in the last few years. The Port Authority of New York

NASM

Bell's X-22A resembled a tight formation of industrial ventilators.

and New Jersey is pushing a civil version to increase air traffic capacity in the northeastern United States.

NASA

Alan Shepard won the 1971 Lunar Open at Fra Mauro.

1971
February 6 Apollo 14's Captain Alan Shepard makes one giant divot for mankind at moon base Fra Mauro. Mission Control in Houston responded, "Looked like a slice to me, Al." Shepard's third drive went about 400 yards—"not bad for a six iron," he gloated.

1986
February 19 The Soviet Union launches Mir, an add-on space station with six docking ports. Last spring an astrophysics module docked with Mir, just in time to survey Supernova 1987A; a second science module may be launched late this year.

. . . and Events

Through February 21 "Black Wings: The American Black in Aviation," Smithsonian Traveling Exhibition. At College Art Center, Middlesex County College, Edison, NJ, (201) 906-2569.

Model youth launch model rockets at the Boy Scout rocket festival.

Billy Grimes

February 5 National Weatherman's Day commemorates the birth of John Jeffries, a physician and balloonist who kept detailed records of weather conditions from 1790 to 1816.

February 12–14 South Florida Boy Scout Association Rocket Launch. At Airglades Airport, Clewiston, FL, (305) 996-3062, ext. 61.

February 18 & 19 "Wings over the Ocean" and "The Golden Age of Flight," lecture and seminar by National Air and Space Museum curators. At the Heard Museum, Phoenix, AZ. Smithsonian National Associates, (202) 357-1350.

March 5 "Telescopes for Everyone," workshop with Geoffrey Chester, National Air and Space Museum. At Louisiana Arts and Science Center, Baton Rouge, LA. Smithsonian National Associates, (202) 357-1350.

March 12–April 11 "Black Wings: The American Black in Aviation," Smithsonian Traveling Exhibition. At New England Air Museum, Bradley International Airport, Windsor Locks, CT, (203) 623-3305.

March 17–20 Soaring Society of America Convention. At Radisson Hotel, Atlanta, GA, (404) 543-2007.

March 18 Total solar eclipse begins in the Indian Ocean, sweeps across northern Pacific Ocean, and ends off southern Alaska.

International Launches

February 1 National Space Development Agency, Tanegashima Island, Japan: Mitsubishi CS-3A communications satellite via an H-1 launcher.

February Vandenberg Air Force Base, California: NOAA-H weather satellite via an Atlas 63E launcher.

Organizations wishing to have events published in Calendar should submit them four months in advance to Calendar, Air & Space/Smithsonian, *National Air and Space Museum, Washington, DC 20560. Events will be listed as space allows.*
—Patricia Trenner

Homecoming

Grueling as *Voyager's* around-the-world flight was, the experimental aircraft's trip to the National Air and Space Museum took much longer. In December 1986 Dick Rutan and Jeana Yeager flew *Voyager* 26,000 miles in nine days. Last July the airplane started a 3,872-mile trek from its home base in California's Mojave Desert to the Museum—a journey that didn't end until late November.

Voyager didn't stop or even refuel during its precedent-setting flight. On its trip to the Museum, however, the aircraft made numerous stops across the country, including an extended July sojourn at the Experimental Aircraft Association convention in Oshkosh, Wisconsin.

To make the journey by truck, *Voyager* had its composite wings clipped. As Rutan and Yeager explained during EAA forums at Oshkosh, the Burt Rutan design had already flown more hours than it had been intended to, and neither pilot had any desire to climb back into the cramped cockpit and fly the dangerous airplane again.

The *Voyager* team recruited a special truck owned by Lee and Gay Penn of Ursa, Illinois, to carry their charge. The Penns' massive 36-wheel vehicle had been designed to haul heavy grading equipment and dredges and is capable of carrying a 70,000-pound load. Leased through PST, Inc. of Utah, the truck had another appealing quality. "Cars don't attack these big trucks," says PST's marketing and logistics director, William Thompson. "This truck is so massive it scares them away."

To prepare *Voyager,* workers at its Mojave hangar first removed the airplane's rear engine and tail booms. Then they used a forklift to gently lower the craft onto the trailer. *Voyager* weighed less than a ton, so weight was no problem, but its wingspan of 108 feet (originally 111, until the winglets were scraped off during takeoff) made it a challenge to load into position. With one wing reaching over the truck's cab and the other jutting out in back, the total length from truck hood to airplane wingtip was a whopping 134 feet, effectively ruling out sharp turns.

On July 16 *Voyager* left the Mojave. The airplane passed through 12 states, traveling at a maximum windspeed of 40 mph (the truck was fitted with an airplane's airspeed indicator), attracting crowds at each stop, and leaving a trail of newspaper stories in its wake.

In early August, having arrived at the Museum's Paul E. Garber Facility in Suitland, Maryland, the airplane cooled its heels until the legal niceties of transferring ownership to the Museum were ironed out. It wasn't until November 20, the paperwork completed, that the airplane was put on display in the Museum.

Howard Wolko, the Museum Aeronautics Department's advisor for technology, considered the task of hanging the airplane in the Museum's south lobby fairly straightforward. "The moving problem with *Voyager* is the headache," he said

Voyager*'s move to the Museum was a challenge of enormous proportions.*

Mark Avino/NASM

before its transfer to the Museum. "A regular wide load, which requires a permit, is 12 feet and can be moved anytime after rush hour. But *Voyager*, even disassembled, is 17½ feet wide and can be moved [from Garber] only after midnight."

After arriving at the Museum well before dawn, the airplane was eased into the building through the west door and squeezed past the Grumman Hellcat and carrier deck display. Once at its display site, the airplane was reassembled and raised, step by step, into position by three hydraulic lifts positioned beneath its tricycle landing gear. By that time, the Museum had opened its doors to the public, and curious visitors joined Museum employees to watch the *Voyager* lifted into position.

The airplane was suspended in place by overhead cables, the lifts were removed, and the landing gear was retracted. Thin cables were attached at the wingtips to give the airplane's wings the graceful curve they had in flight. Even raised, though, the right wingtip hovers a mere nine feet above the gallery floor.

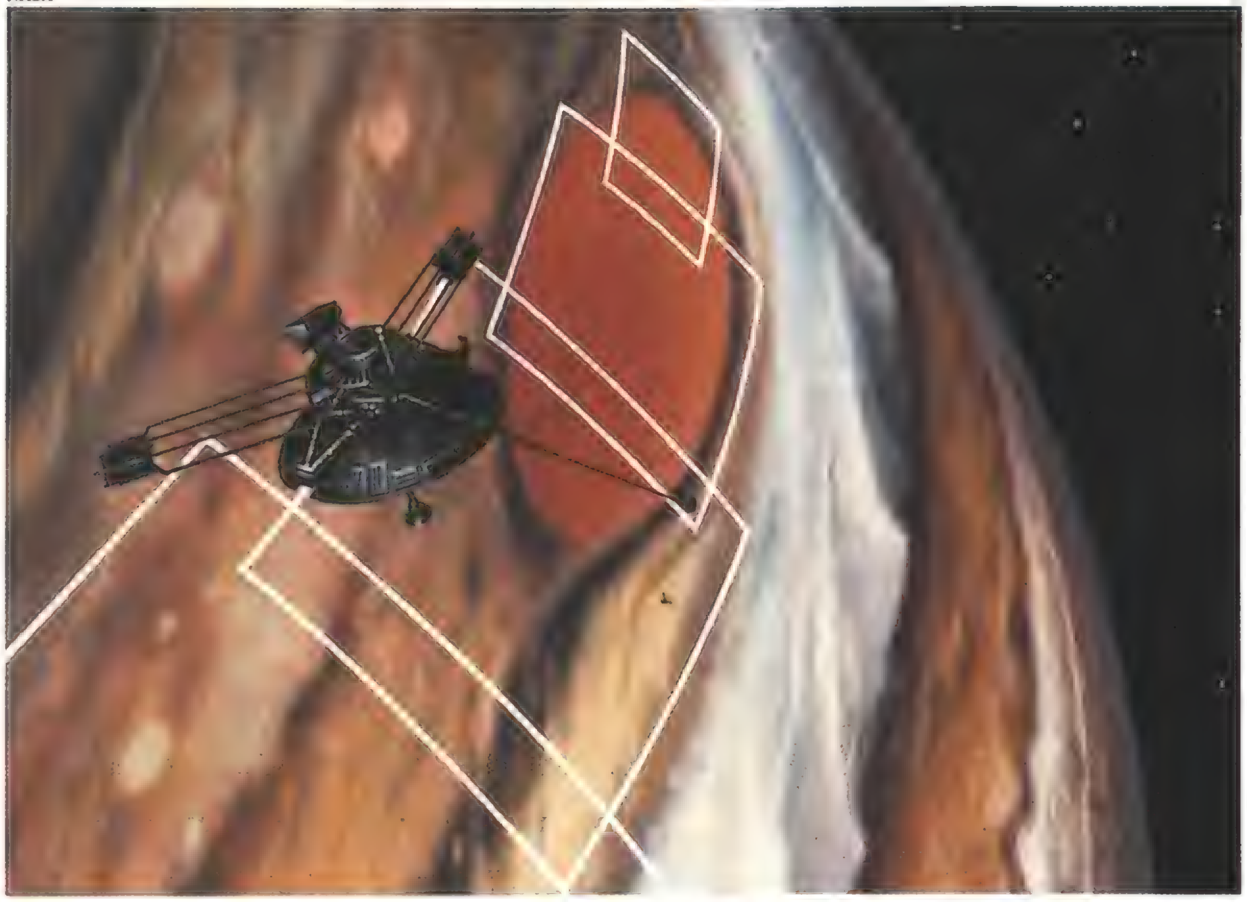
Voyager is displayed as if in flight, banking in a gentle turn to the right. Its wingtips, left torn and ragged after the loss of the winglets, have not been restored. The Museum's desire to display the airplane unchanged extended to preserving its odd paint job. The *Voyager* team had left the bottom of the airplane unpainted to keep weight down. "It's not as pretty as the pictures, which were taken from the top," Wolko says.

Almost directly above *Voyager* on the Museum's second floor sits the Douglas World Cruiser *Chicago*, one of two airplanes that completed the first aerial circumnavigations of the globe in 1924. Of the four airplanes that left Seattle on April 6 on that pioneering voyage, only *Chicago* and its sister ship *New Orleans* completed the journey.

The 62 years between those epic world flights have encompassed revolutionary changes in aviation. Nowhere is the contrast more evident than in the comparison between *Chicago* and *Voyager*. One is a fabric-covered biplane, the other a sleek craft constructed out of the latest in composite technology. *Chicago* has an open cockpit; *Voyager*'s two pilots were wedged inside a tiny fuselage, peering ahead through a plexiglass bubble. It took *Chicago* five months and many refueling and repair stops to finish its flight. Despite the technological gap between them, the two aircraft, having both made unprecedented flights around the world, are kindred spirits.

—Tom Huntington, Managing Editor

NASA



A Simpson experiment traveled aboard Pioneer 11 as it photographed Jupiter.

A Place in History

Some of the best brains in U.S. space science have been taking a break from the lab to put the past in order at the Museum. These pioneering souls are occupants of the Museum's Martin Marietta Chair in Space History, established in 1985 to draw leading figures in the nation's space program to the Museum to prepare accounts of their historic projects.

The man in the chair for 1987-88 is cosmic ray physicist John A. Simpson, 71, founder of the Laboratory for Astrophysics and Space Research at the University of Chicago's Enrico Fermi Institute for Nuclear Studies. During the Halleymania of 1986, Simpson gained fame as the only U.S. scientist with an experiment on the Soviet Union's mission to study Halley's comet. The two Vega spacecraft that encountered the comet carried dust collectors designed and built by Simpson. (A duplicate of one of these collectors is displayed in the Museum's Exploring the Planets exhibit.) Simpson's interest is comparing cosmic rays and comet dust to see if they are of similar composition—hence of similar origin.

In 1983 the Museum's curator of planetary spacecraft, Allan Needell, visited Simpson to search his files for material to add to the Museum's archives. "It was like letting a kid loose in a candy store," Simpson recalls. Soon after, he was invited to work at the Museum.

Early last year, Simpson decided to accept. The lab at Fermi was rather quiet; with spacecraft launches delayed, the business of space experimentation was slow. Simpson gave up his professorship, retaining his office at the lab, and came to Washington last fall.

The physicist brought with him a distinguished background. After working in the metallurgy lab of the Manhattan Project—formed at the University of Chicago in the 1940s to develop an atomic bomb—Simpson turned his focus to cosmic rays. Highly energetic atomic particles believed to be thrown off by supernovas and other powerful galactic sources of energy, cosmic rays may reveal how matter is formed when stars are born and die.

Because Earth's magnetic field keeps all but the highest-energy cosmic rays from piercing the atmosphere, Simpson followed a series of airborne studies of cosmic rays in the 1950s with a series of space-based observations beginning in 1958. Since then, Simpson has flown experiments on more than 20 spacecraft, some of which are still relaying data to Earth.

Simpson's first task as space historian is to record the story of how he surmounted stringent limits on the export of U.S. technology to the Soviet Union to participate in the historic comet encounter. With Soviet officials soliciting international participation on upcoming space missions, Simpson says he'd like to do it again.

Most of the salary allotted to Simpson as space historian will go toward archiving his immense collection of papers and scientific

data, now stored at the University of Chicago's Regenstein Library. The stockpile includes 6,500 magnetic tapes and more than 200 boxes of papers, all stashed away in no particular order. Staff at the library and the Museum will work together on the project.

As an occupant of the space history chair, Simpson is in good company. The first to take advantage of the opportunity was solar astronomer Leo Goldberg, a former director of the Kitt Peak National Observatory in Arizona. Simpson's immediate predecessor was X-ray astronomer Herbert Friedman.

Friedman went to work at the Naval Research Laboratory in 1940, where he remained until his retirement 40 years later. His job may have been stable, but his career has been anything but boring: like Simpson, he was closely involved in the earliest days of space-based research.

During his year at the Museum, Friedman prepared articles on the launching of space experiments on V-2 rockets in the late 1940s and 1950s, early work on galactic X-ray astronomy starting in 1957, and the boom in satellite astronomy from 1960 to 1975. "Each article stands on its own as a little piece of history," Friedman says.

How will all this history affect the exhibits in the Museum? Friedman believes the Museum does a wonderful job telling the stories of people and their machines, but the task of putting together a science exhibit that will stir public enthusiasm is much more difficult. The more curators know about the people behind the space missions, the more interesting their science exhibits can become.

While the scientists' work in the Museum is undoubtedly a boon to space historians, the scientists themselves also benefit—sometimes in unexpected ways. Friedman, for example, notes that one windfall of his year at the Museum was learning how to write on a word processor.

That skill should come in handy. Friedman is now a scientist emeritus at the Naval Research Laboratory and senior editor of a new series of books on space science and exploration to be published by Harvard University Press.

Both Friedman and Simpson are still involved in myriad space missions: Friedman, for example, is involved in planning for NASA's Gamma Ray Observatory, to be launched in 1990; Simpson, in the U.S.-European Ulysses spacecraft to be launched in 1990 on a mission around the poles of the sun. Neither man, it appears, is the retiring type.

—Linda Billings, Senior Editor/Space

Go Fly a Kite

Controversy is as much a part of Washington as monuments. But of all controversies in past decades, surely one of the more improbable surrounded the flying of kites. An 1892 statute entitled "An Act for the Preservation of the Public Peace and the Protection of Property Within the District of Columbia" made kite flying there illegal. Some 20 years ago, Paul Garber, now the Museum's Historian Emeritus, led kite-flying Washingtonians in getting the statute reversed. This March 26, for its 22nd year, the Annual Smithsonian Kite Festival celebrates the art and joy of flying a kite (see below for details).

Caroline Sheen

Caroline Sheen

Museum Calendar

Except where noted, no tickets or reservations are required. Call Smithsonian Information at (202) 357-2700 for details.

"First Encounters" Film Series. Fridays, 7:30 p.m., Langley Theater. February 5: *Invasion of the Body Snatchers* (1978). February 12: *Monolith Monsters* (1957). February 19: *Star Man* (1984). February 26: *E.T.: The Extraterrestrial* (1982; admission $1).

February 6 Monthly Sky Lecture: "Life and Death in the Winter Sky." James O'Leary, director, Davis Planetarium, Maryland Science Center. Einstein Planetarium, 9:30 a.m.

February 11 General Electric Aviation Lecture: "Winning by a Rotor." Wing Commander Kenneth H. Wallis, Royal Air Force (Ret.). Langley Theater, 7:30 p.m.

February 17 Exploring Space Lecture: "The Invisible Universe Revealed: New Discoveries in Radio Astronomy." Gerrit Verschuur, National Radio Astronomy Observatory. Einstein Planetarium, 7:30 p.m.

March 5 Monthly Sky Lecture: "The Wandering Earth." James H. Sharp, planetarium director, NASM. Einstein Planetarium, 9:30 a.m.

March 12 Kite display, lecture, and distribution of rules for the Smithsonian Kite Festival (see March 26 listing). Baird Auditorium, Museum of Natural History, 10 a.m.

March 16 Exploring Space Lecture: "The Violent Universe." Herbert Friedman, Naval Research Laboratory. Einstein Planetarium, 7:30 p.m.

March 24 General Electric Aviation Lecture: "100 Missions North: Reflections of an F-105 Pilot." Brig. Gen. Ken Bell, U.S. Air Force (Ret.). Langley Theater, 7:30 p.m.

March 26 22nd Annual Smithsonian Kite Festival. Competition of handmade kites. Washington Monument grounds, west side, 10 a.m. (Rain date: March 27.)

The Three Bs

As a boy I devoured pulp science fiction magazines like *Thrilling Wonder Stories* and its companion, *Startling Stories.* It wasn't the tales so much that attracted me—those were mostly stock soap operas that revolved around spaceships, time travel, and atomic fallout. I was more interested in the covers, which usually featured the classic three Bs: a Bum, a Babe, and a BEM.

Of this triumvirate, the Bum was a muscular male; the Babe, a scantily clad female; and the BEM, a Bug-Eyed Monster. The Bum was invariably pictured wielding a sword, of all weapons, to protect the Babe from the BEM.

What happened to the BEMs of my boyhood? Sadly, when I was drafted into the Army my mother purged her basement of pulps and comics—which if owned today would enable me to finance my own space shuttle.

But tattered and yellowed copies of these classics do exist in some fans' collections and in scattered libraries, including the one at the University of Wisconsin at Milwaukee, which I visited during a recent quest for BEMs. There in the special-collections room were entire shelves packed with bound volumes of *Thrilling Wonder Stories* and *Startling Stories.*

As I scanned the pulps, I realized that only occasionally did the tale include a true BEM. One appeared in a Frank Belknap Long story in the May 1948 *Startling*: "The beast had the snout of an anteater, but it was covered with down like a new-hatched chicken. It was fanning itself with a tail of blood-red plumes that grew straight out of its hindparts, and was almost as big as the spread tail of a peacock."

But most of the BEMs, it seemed, lived on the covers. When I opened one of the library's volumes I encountered a giant eye rimmed by 11 smaller ones, all belonging to a prototypal Bug-Eyed Monster. It graced the cover of the November 1948 *Startling Stories,* the creation of a painter named Earle Bergey. Bergey drew the BEM, a startled Bum in its tentacles, levitating into space, despite the admonitions of a Babe in bra and filmy skirt.

Somehow Earle Bergey captured BEMs—and adolescent imaginations—more capably than the authors by selecting a few sentences and translating them into a lurid cover capable of leaping off the newsstands and into our hands. The June 1949 *Thrilling Wonder* showed Bum and Babe swinging swords against giant lizards. On the February 1948 cover, it was a giant fly. For August 1947, a green monster with three eyes rose from a swamp to be roasted by the Bum's flamethrower as the Babe stood calmly by, combing her long, blonde hair.

One might dismiss such publications as trash, but some stories did stand out from the space opera counterparts. Cover-lined on the November 1948 *Startling Stories* was a novel—*Against the Fall of Night*—by a science fiction writer described as popular in Great Britain but new to this side of the Atlantic: Arthur C. Clarke. And relegated to the back of the book was a short story titled "The Visitor" by another author, Ray Bradbury, whose name and reputation have survived four decades.

The editors deserved some praise for occasionally discovering these novice sculptors of STF (the magazine's code name for "scientifiction"), but their names never appeared on the masthead. As far as the readers knew, the editor was Sergeant Saturn, who engineered the departments "The Reader Speaks" (in *Thrilling Wonder*) and "The Ether Vibrates" (in *Startling*). It was up to "the Sarge" to field letters from readers who felt obligated to comment on every article and drawing in the previous issue.

Undoubtedly, some of those readers eventually went to work for NASA, probing the true frontiers of space. How many of those monitoring computers at Mission Control when Neil Armstrong set foot on the moon wondered whether there might be a BEM lurking behind a boulder? They must have been disappointed: Armstrong, invisible inside his pressurized suit, hardly looked like a Bergey-drawn Bum, and he had neglected to bring a Babe.

Subsequent astronauts have not encountered any BEMs, even though odds are they do exist, and not merely in the imaginations of vintage-STF wordsmiths. Given a billion or more stars, there might be a trillion or more planets circling them, *some* of which must support life. If we traveled to the next galaxy and selected a promising planet, we would be more likely to run into a BEM than a PLU (Person Like Us).

Covers of science fiction publications today, particularly paperbacks found in airport terminals, seem tamer than the paintings from my boyhood. BEMs have been replaced by robotic machines similar to HAL, the evil computer in the film *2001: A Space Odyssey.* Bums used to dash around bare-chested; now they wear astronaut suits. Babes in see-through gowns appear more often in the pages of *Playboy.* And even the very essence of the BEM—evil—was refuted by Steven Spielberg's *E.T.: The Extra-Terrestrial.*

Perhaps the realities our space probes have revealed—the boiling atmosphere of Venus, the barren plains of Mars—have convinced STF practitioners that they should abandon neighboring planets as settings for the three Bs. And when a supernova thousands of light-years away flares in our southern skies, fact does seem more thrilling than fiction.

—Hal Higdon

Remember the day you
took off your training wheels?

Legs pumping. Feet flying. You flew. No longer would you be held back. Or slowed down. This was the ultimate pleasure. You had grown up.
The new Audi 90 brings forth similar feelings.
Here is a car that matches your passion for performance.
Five cylinders produce 130 HP. Sixty is reached in 8.5 seconds. Top track speed is 128 MPH.
Handling is enhanced by front wheel drive. Steering is precise and quick. The basic suspension design rallye proven.

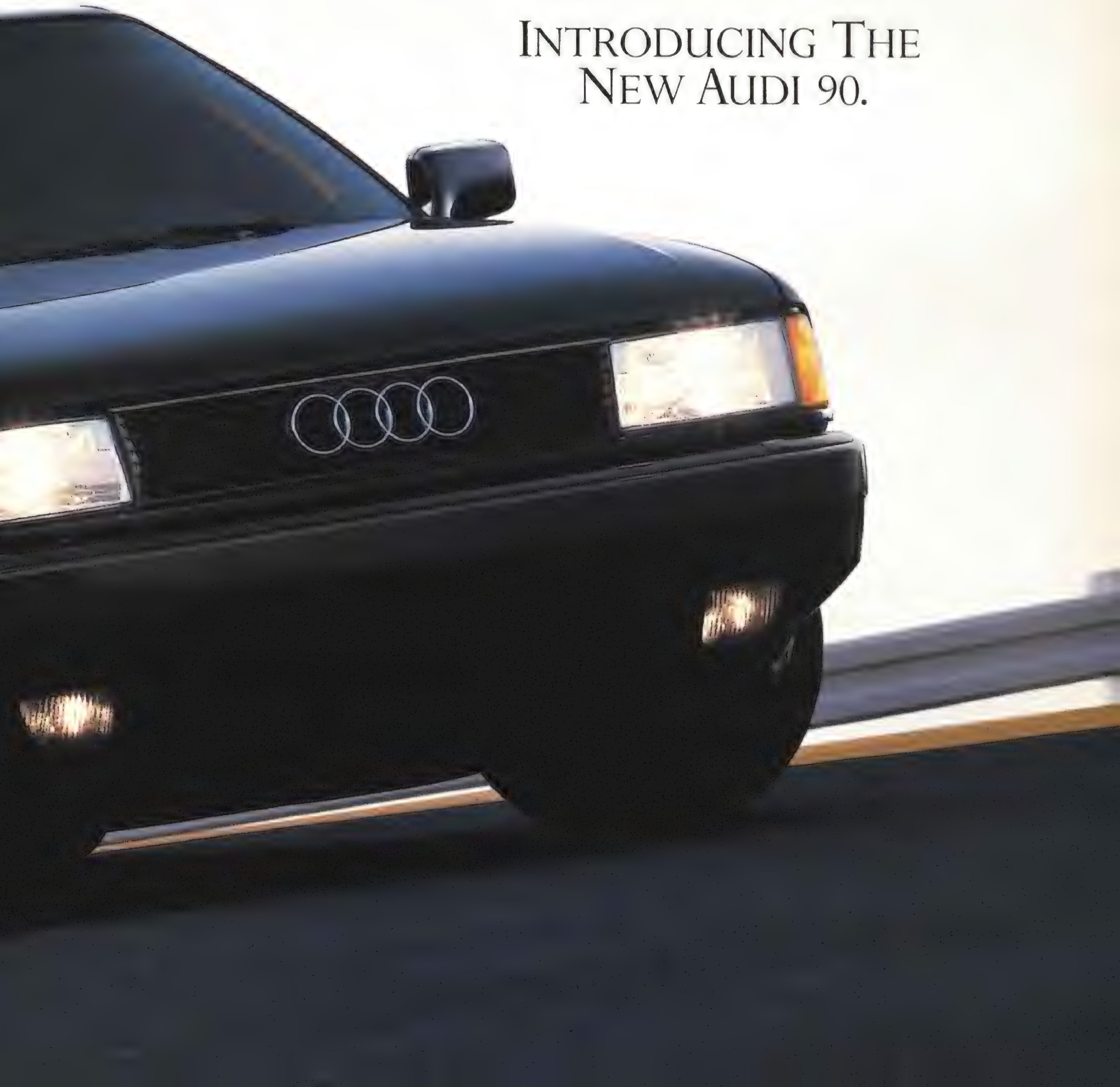
The engine smooth revving. And soundly satisfying.

An Anti-Lock Braking System (ABS) is standard. Quick stops from speed are more easily controlled.

Sporty leather seats hold you firmly. You ride secure. Senses alert. Every control at your fingertips. All is in harmony. You and the car are one.

Driving is what you hoped it would be. When you were a kid. On a bike. On your own.

INTRODUCING THE NEW AUDI 90.



Looking for Earhart

I didn't decide to become an aviator until after graduation from the Naval Academy. At the time, I was serving aboard a cruiser and the skipper was very reluctant to see me go. Not that I was that good an officer—he just didn't care much for aviation. But when his daughter married an aviator he relented and approved my transfer to flight training.

When I finished, I was assigned to a Scouting Squadron aboard the aircraft carrier *Ranger.* I flew the Vought SBU Corsair, a rugged and reliable fixed-gear biplane the Navy used as a scout-bomber.

It was while I was stationed aboard the *Ranger* that I became involved in the search for Amelia Earhart, who was lost on her attempt to fly around the world. She was an experienced aviator with a number of risky flights and firsts to her credit, including the first flight from Hawaii to the U.S. mainland and another solo flight across the Atlantic. For her world trip, she and navigator Fred Noonan were flying west to east, roughly along the equator, in a twin-engine Lockheed Electra.

They set out June 1, 1937, from Miami. On June 29 they arrived at Lae, New Guinea, and were poised for the longest nonstop leg of the trip, 2,556 miles across the South Pacific to a refueling stop at tiny Howland Island.

This leg would demand the most of Noonan's navigational abilities. Once a navigator for Pan Am, he had helped that airline establish routes in the South Pacific, so he was as familiar with the area as anyone could be. To help guide them in, a Coast Guard cutter named the *Itasca* had been stationed near Howland and Baker Islands.

Earhart and Noonan never made it to Howland, though they apparently came heartbreakingly close. The radio operators on the *Itasca* could hear Earhart calling them, but apparently the two aboard the Electra could not hear the *Itasca.* The airplane, Earhart, and Noonan disappeared without a trace in the broad reaches of the Pacific.

The news of Earhart's disappearance hit the newsstands on the Fourth of July weekend, but by then the Roosevelt administration had authorized the Navy to begin preparations for a search. The carrier *Lexington,* preparing for holiday festivities at Long Beach, California, was ordered down to San Diego. In the meantime an air group, including my squadron from the *Ranger,* was being organized at the Naval station at North Island. Because fighters had limited fuel capability and were single-seaters with no room for observers, the air group consisted of scouts and bombers, supplemented by two amphibious airplanes from the carrier.

Illustrations by Richard Parisi/Bill Burrows and Associates

Fourteen airplanes from each of six squadrons flew aboard the *Lexington,* while maintenance and enlisted personnel for the squadrons arrived by small craft. Three destroyers—the *Cushing,* the *Drayton,* and the *Lamson*—were assigned to this hastily organized search mission.

Most of us came aboard the *Lexington* thinking that we would only go out a thousand miles or so before the whole thing was called off, so we brought along only an overnight bag with a pair of pajamas, a razor, and perhaps a change of underwear. As it turned out, we stayed aboard for a month and eventually had to buy clothes from the ship's store.

We left on July 5, making good speed for Hawaii. In fact, our trip was the fastest ever made to Hawaii at the time. As we approached the islands the destroyers peeled off to refuel at Pearl Harbor. The *Lexington* refueled at Lahaina Roads, on the island of Maui. Normally the *Lex* and her sister carrier *Sara*—the *Saratoga*—would fuel only to 95 percent capacity because the weight of the eight-inch guns and the carrier's island on the starboard side would make a fully fueled ship heel over about three degrees. Nonetheless, we fueled 100 percent, then on the way to Howland we burned the fuel from tanks on the starboard side first until the ship was back on an even keel.

Other ships had done some preliminary searching in the area before the *Lexington* arrived. One was the *Itasca;* another, the battleship *Colorado,* had three Curtiss seaplanes onboard that were launched by catapult.

We started our search on July 13 with a plan that had been devised by the ship's senior officers on our trip out. One destroyer stayed with the carrier as the plane guard, meaning it would rescue anyone who went overboard on takeoffs or landings. The other two destroyers were deployed to port and starboard about 60 miles out. Each search entailed 48 aircraft. Smoke bombs were dropped off the ship's stern, and the first airplanes to take off dropped two smoke bombs off the bow. Twelve airplanes circled each smoke bomb, and at a given signal 24 airplanes formed a line on each side of the ship and began flying away from each other, 90 degrees from the ship's course. After flying 120 miles out, each line made a 90-degree turn and flew in one long column for 24 miles. Another 90-degree turn brought the two lines back toward the ship.

We kept the airplanes separated by a mile and flew at 500 feet, and the sight of 24 aircraft stretching across the horizon was impressive. The line was ragged the first couple of times out, but we eventually got pretty damned good at it.

During the flights, which lasted about three hours, the pilots all gazed toward the center of the line and the rear-seat men looked in the opposite direction with binoculars, ensuring that the ocean was covered thoroughly. Each of us was anxious to be the first to sight Earhart and Noonan

or any clue to their fate, so we paid close attention to the ocean below us. We figured that they would be in a rubber boat, and from our altitude we could see anything—garbage, trash—floating in the water. If there had been a life raft or a life jacket, we would have seen it, but there was nothing more than an occasional bit of flotsam to arouse hope.

We were all conscious of the adventurous nature of our mission. And as we covered miles and miles of empty ocean, we got a good idea of how the two in the Electra felt as they searched for a tiny bit of land in an endless sea.

The search mission took 10 days, during which we covered 250,000 square miles, an area the size of Texas, to a density of one-half mile. And in all that air time there were no accidents, a remarkable performance for such concentrated flying. But of course we weren't abusing the airplanes by dive-bombing or strafing. We flew at cruising speed and then made carrier landings under good conditions.

Two searches were flown each day, with each crew flying twice one day and once the next. The rest of the time, naturally, was spent on the ship. They say that an aircraft carrier is a poker game with a flight deck over it, and we did play a lot of cards during that month at sea. Those who didn't care for poker could play basketball, volleyball, or badminton on the hangar deck. We also watched movies, but we had only two on board and it wasn't long before we had them both memorized. One was a Rin Tin Tin movie, and every time the dog barked the whole crew barked along.

Of course, we never found a trace of Earhart, Noonan, or their Electra. Some people have speculated that Earhart had been on a secret mission to spy on the Japanese in the Marshalls and on Truk Island, but I think the idea is absolutely ridiculous. Others have suggested that the Japanese shot her down and held her prisoner, but I discount all that.

I believe that Earhart and Noonan, perhaps blown off course by winds during the night, missed Howland Island. As navigator, Noonan would have tried to use the sun to calculate their longitude, then hoped that by running north and south they would pass over the island. In fact, the last radio communication from the Electra indicated that this is precisely what Earhart and Noonan were doing, as their gas gauges crept toward empty and their world flight approached its tragic end.

On July 23 the Navy called off the search mission and we headed home. But first we put all the airplanes in the air and flew over the equator on the International Dateline. It's an old nautical tradition that people who cross the equator become "shellbacks," so we had the privilege of painting a flying turtle on each airplane. On the way back to San Diego we didn't have any air operations, since we only had about enough fuel left to fly the airplanes off when we got back to port.

One thing we didn't run out of during the entire search was steak. Apparently they had just stocked the cold storage aboard the *Lexington,* and it seems to me we had steak nearly every meal until we started to get sick of it. And when I got back to San Diego my mother and brother met me and took me out—for a steak dinner.

—Rear Admiral Francis D. Foley (Ret.)

Sweden's 'Flying Weapon'

What's a nice country like this doing with such a hot air force?

by Steven L. Thompson

Every year, at the world's great airshows in Farnborough, England, and at Le Bourget, France, a curious convocation of like-minded souls gathers to celebrate the Swedish air force. They call themselves the Swedish Air Force Fan Club, and those who meet to toast the Swedes come from business, journalism, and other nations' military services.

There is something peculiar about this. In the world's military aviation community, nobody gets points for having great logistics or nice uniforms. What counts is the win-or-die performance best evaluated in combat. So how does having an air force—the *Svenska Flygvapnet* or, literally, "Swedish Flying Weapon"—that elicits such admiration from international aviation experts square with a pacifistic, dedicatedly neutral nation that hasn't fought a war in almost two centuries?

For hardware junkies, one point of admiration is the Flygvapnet's equipment. To be sure, the Saab aircraft factory in Linköping and the Volvo Flygmotor engine plant in Trollhättan

Bo Dahlin

A Swedish-built JA37 Viggen thunders forth from its wooded lair. The short-takeoff-and-landing jet, able to operate from roadways only 550 yards long, is ideal for deployment at bases hidden throughout the country.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have made some pretty impressive fighters since World War II. When it first flew in 1955, the J35 Draken, for instance, was the world's first double-delta-winged supersonic interceptor. And its successor, the JA37 Viggen, was the first canard-equipped supersonic fighter when it took flight in 1967. So it's easy to see how guys who spend their leisure hours poring over Jane's *All the World's Aircraft* can be so enamored of the Swedish air force.

But there's obviously something else about the Swedes that makes them so special. After all, where are the French air force fans? And who's ever heard of a Soviet Frontal Aviation fan club?

What initially strikes an American exploring Sweden, its people, and its air force is the absence of some key cultural landmarks—World War II, for instance. For our armed services—indeed, for our whole society and much of the rest of the world—what is still known as "The War" changed everything. Far less so in Sweden.

The nation's air force, though, *was* deeply changed. While Swedish politics kept the country out of the fighting, Swedish politicians abandoned their pacifist dreams and declared that no one should expect to walk in and take over Sweden without a fight. They began arming the air force with considerable seriousness.

As Major General Bengt Lönnbom, air force chief of staff, asserts, the *raison d'être* for the Flygvapnet is still Sweden's bulldog determination to keep all invaders out of its territory. To accomplish this, Lönnbom oversees a force of some 12,500 regular air force personnel (military and civilian), slightly more than 500 of whom are pilots who fly more than 650 aircraft. (Getting accurate personnel and hardware figures from the Flygvapnet is not easy, evidently because the Swedes have become more security-conscious since a Soviet patrol submarine beached itself inside the secret zone of the Swedish navy's Karlskrona base on October 27, 1981. When asked how many aircraft were on hand to fulfill his wing's air defense mission, one commander tartly replied, "Enough.")

Of those airplanes, the vast majority—about 500—are fighters; the rest are fighter-bombers, reconnaissance aircraft, trainers, and a very few air transport vehicles. This profile alone tells you something remarkable about the Flygvapnet: first, that its numbers are very large indeed for such a small country, and second, that it really must be a purely defensive force, since it does not have any long-range bombers for power projection.

Christopher Springmann

Sweden's air force may not look like those of other countries, but its uniqueness is more than cosmetic: it has roots deep in the nation's culture.

Compare the Swedish air force with others and you see immediately the tremendous commitment the country has made: Sweden has 500 fighters ready to defend about 8.3 million people and 173,000 square miles of land, while France, with 221,000 square miles and more than 55 million people, has only about 200 more tactical aircraft. When you consider that France has good reason to arm itself, what with two invasions in a generation, and that Sweden has been left in peace, the Swedish government's investment in air defense seems immense.

Among smaller nations, only Israel, with nearly 1,000 tactical airplanes serving about four million people on less than 8,000 square miles, boasts a greater per-capita air combat capability. Again, though, Israel has engaged in combat in every decade since its creation in 1948. Furthermore, while Israel reluctantly abandoned plans last year to build its own fighter, the Lavi, Sweden continues to build the overwhelming majority of its own combat airplanes, as it has done since World War II.

As Lönnbom and his staff explain it, this was not the result of chauvinism but of strategy and history. The Swedes had set out to equip their air force at the outbreak of World War II by buying from foreign suppliers, but hostilities halted the flow of weapons, convincing defense planners that a Swedish aviation industry—then in its infancy—was literally the only way to fly. Established in 1937 in what was a railroad engineering firm's plant near Trollhättan in southwestern Sweden, the Svenska Aeroplan Aktiebolaget, better known as Saab, grew up quickly. Although the end result may suggest a "buy Swedish" policy, Colonel Kent Hårrskog of the Air Staff asserts that the Swedes' prime concern is using the best equipment, regardless of its origin.

Air Staff officers say that as events unfolded in the postwar years, another advantage of Swedish-built combat aircraft became apparent. An all-Swedish fighter would make an aggressor's job a gamble against unknown odds—he wouldn't know what to expect from the Flygvapnet's fighters because only the Flygvapnet flew them.

While this makes sense, the high cost of developing combat aircraft, especially for so small a nation, makes export efforts extremely attractive. In fact, the Swedes have never passed up an opportunity to attempt exporting their hardware, and they even rigorously marketed their Viggen against General Dynamics' F-16 in the late 1970s when many NATO air forces were shopping for replacements for old interceptors. But currently, only Austria buys Saab fighters in volume.

Sweden has other, more practical, reasons for building its own aircraft. Since the nation does not intend its fleet

J35 Draken fighters present a stalwart front at the F10 Wing at Ängelholm in southern Sweden. The Draken, introduced in 1955, has been largely replaced by the Viggen, but some will remain in service until the mid-1990s.

Peter Liander

to fly anywhere but over its own territory, the aircraft need be customized for only one operating environment. And who knows better what a Swedish winter is like than a Swede?

The advantage of such specialized aircraft is highlighted by another unique aspect of the Flygvapnet: its covert dispersal tactics. Air force tacticians reasoned that because they were outnumbered by each superpower's air force, hiding their assets was vital to avoiding the kind of devastating sneak attack that the U.S. Army Air Corps suffered at Pearl Harbor. Thus, long before U.S. and European planners became concerned about losing their bases' runways to cratering weapons, Swedish air force pilots were flying their Drakens and Viggens from remote sites deep in the forest, using public roads as runways and hiding their airplanes in tunnels. Swedish aircraft are therefore designed for quick and easy maintenance and the ability to take off and land on short roads.

So the Swedes have a large force of interceptors and a bunch of pilots skilled enough to fly heavily laden supersonic fighters off snow-covered back roads. What does this really say, though, of their readiness to defend their country?

Colonel Göte Pudas, chief of flying at the Air Staff, notes that in 1982, Viggen and Draken pilots scrambled to intercept 293 unknown and potentially hostile aircraft. More than 500 visual contacts with such aircraft are made each year. Of those, about 25 contacts and interceptions will result in official government action.

But willingness to enter combat may be impossible to measure outside the test of combat itself. In evaluating his air force's fitness, Lönnbom makes clear that since history has not tested the Flygvapnet, neither he nor any other pilot or officer can comment accurately on its ultimate performance. But they train as hard and realistically as possible, he says, and they try to learn everything they can from everybody who has flown in air combat.

The effort, of course, bears a distinctly Swedish flavor. In Sweden, the same social forces that have preserved the oft-noted Swedish placidity have also touched every part of Swedish culture. Decades of the Social Democrats'

Christopher Springmann

Before taking on the Flygvapnet's fighters, future pilots learn in small, easy-to-fly SK60s. From this SK60, a nearby Viggen is visible.

Sweden's Burgeoning Space Program

During the summer, the sky over northern Sweden's Esrange space center is still light at midnight and the clouds are tinted pink. Here above the Arctic Circle the summer twilight never quite darkens to night. As the countdown for a multiple rocket launch booms over loudspeakers, a pair of huge parabolic antennas turns to eavesdrop on another sector of the illuminated night sky, like the ears of Lapland reindeer swiveling in the direction of a sudden sound.

Esrange, near the iron mining city of Kiruna, has been the launch site of sounding rockets and research balloons for over two decades. In addition, the state-owned Swedish Space Corporation (SSC), which now administers Esrange, uses the center to track and control the satellites of European Space Agency (ESA) members and other nations.

SSC

Fire and ice mark a rocket launch at Sweden's Esrange space center.

Sweden's space program was inaugurated in February 1986 by the successful liftoff of the first Swedish-built satellite, Viking. Shaped like a smashed teakettle and weighing less than a small car, Viking measured electrical and magnetic fields, waves, particles, and ultraviolet emissions from the aurora borealis for 15 months. But only the tracking and controlling were done at Esrange; because the Swedes lack the facilities for launching satellites, Viking was sent aloft on a European Ariane rocket from French Guiana in South America.

A recent study commissioned by the SSC could help change the situation. Submitted to the ESA late last year, the study concluded that there will be a market for a small-satellite launcher in the next decade. By constructing and launching a mini version of Ariane, whimsically called Marianne, Esrange could become the only facility in Western Europe capable of launching small satellites on a commercial basis. The ESA, in conjunction with the SSC, will examine the issue in more detail this year. The Swedes hope to be launching satellites by the late 1990s, although launch sites in Norway and French Guiana are reportedly also under consideration.

While small scientific or commercial satellites have been riding piggyback with larger payloads on the U.S. space shuttle or Ariane, problems with the launch vehicle or main payload sometimes cause serious delays. Marianne would offer its customers the appeal of a smaller, simpler rocket dedicated solely to carrying their satellites. Such a plan has grown increasingly attractive in light of the grounding of the space shuttle and delays in Ariane launches.

In the two decades the Swedes have been launching research rockets and balloons at Esrange, they have developed a high level of technical support services, including 80 full-time employees and almost every tool and machine needed to repair a rocket. "We're being pampered here," said NASA engineer David Kotsifakis, at Esrange to study the electrical charges around noctilucent clouds—high-altitude clouds invisible to the naked eye.

The SSC's satellite ground station is a short drive from the rocket range. After midnight one night late in July, Swedish technicians there were monitoring a Japanese EXOS-C satellite, the French SPOT satellite, and two U.S. Landsat satellites. According to Esrange director Arne Helger, discussions are currently under way with Japanese, Chinese, and Indian representatives regarding other possible satellite tracking contracts. This year Esrange will begin to track and control a Japanese remote sensing satellite called MOS-1; the following year, it will be responsible for tracking and controlling a Scandinavian telecommunications satellite called Tele-X, scheduled for an early 1989 launch.

Not everyone welcomes Sweden's booming space program, however. Members of the nearby Lapp village of Talma use the rocket range impact area as winter foraging grounds for their reindeer and are concerned about plans for the growth of Esrange.

A reindeer herdsman from Talma, Lars Jon Allas, says government officials have not protected the interests of his people. Lapps (called *Samer* in Sweden) have herded reindeer, hunted, and fished here since the end of the last ice age. They are still reeling from the nuclear catastrophe at Chernobyl, which made many of the semi-wild reindeer on which their culture depends unfit for human consumption. "We want a secure future for us and our descendants," Allas says. That future seems destined to mix rockets and reindeer.

—David Bartal

Bo Dahlin

determination to level the peaks and valleys of Swedish society—including the military—have resulted in some customs novel to an outsider.

There are, for instance, no noncommissioned officers in the Flygvapnet, only officers and "conscripts." The Flygvapnet has no John Wayne-like top sergeants to enforce military discipline because there are no sergeants at all. All NCOs were summarily commissioned a few years ago when the government, urged by unions, decided that the modern air force had no reason for such a "caste." Likewise, the raw recruit who fails to snap a razor-sharp salute at his colonel receives not an immediate dressing-down but a polite nod in passing—if he is noted at all. And in flight training, in which many an air force uses sometimes savage techniques to assure graduation of only a select few recruits, Sweden's air force again has its own way.

A would-be Flygvapnet jock must have done mandatory service time but is not required to have a university degree—although he must have done well enough academically to qualify for entrance in a university. He is screened physically and mentally, the ultimate test being the DMT, or Defense Mechanism Test, developed in the 1950s and refined for use in the 1960s. Designed to sort people into three categories according to their perceptions of and reactions to threats, the multilayered DMT presents candidates with visual stimuli and a series of questions about their responses to the images. The well-guarded technique was finally accepted by Flygvapnet when extensive testing showed that a pilot who did poorly on it was seven times more likely to crash in an avoidable accident than a pilot who scored high.

Instead of taking in 300 eager would-be Top Guns and finding the desirable 20 percent by ruthless application of time-proven washout tactics, the train-

At the commercial pilot school, a cadet and her instructor return from a flight. Although welcome as civilian pilots, women are not trained to fly in the air force.

Christopher Springmann

Like all Flygvapnet officers, Major General Bengt Lönnbohm wears no medals and relatively little gold braid—part of an effort to rid the military of class distinctions.

ing center at Ljungbyhed in southern Sweden accepts only 80 trainees and graduates not 20 percent but almost all. Of these 80, half have chosen to train as air force pilots and half will train to become commercial pilots in a state-supported commercial pilot school, also at Ljungbyhed. The same methods of screening and training are applied to both groups. Captain Tore Jansson, a training squadron pilot and commander, explains that it is considered better to have a lot of reliable, highly competent pilots than a few stars and many lesser lights.

All Flygvapnet pilots are trained at the same school at Ljungbyhed, known by the base's number: F5. There they undergo a training regimen similar in outline to that any pilot must endure. They begin training in a light, piston-engine airplane, graduate to 210 hours in a turbojet, and finally move on to the "big jets" like the Viggen.

The big difference at F5 is the ambiance: the instructors do not hammer on the students to simulate the stresses of combat. Instead, F5's instructors work to reduce the stress of training, teaching the student to relax, keep up his confidence, and consider his instructors almost as friends. Official policy views an impending washout of any trainee as the instructors' fault, not the student's.

Predictably, the movie *Top Gun* was

Christopher Springmann

A touch of whimsy brightens an otherwise imposing ground training facility for Viggen technical personnel.

Bo Dahlin

A formation of Lockheed C-130s lumbers over western Sweden. Around age 40, air force pilots are reassigned to duties less demanding than flying fighters, such as piloting one of the eight Hercules cargo planes in the Transport Squadron.

Sweden's new Gripen fighter should make its first flight by mid-year. Until the jet enters service in 1992, the ambitious program will consume nearly one-third of the nation's defense budget. But a single Gripen will carry out three roles: it is a fighter, attack, and reconnaissance jet all in one.

popular at F5 and among Swedish air force pilots. But the critical element of the story is officially denied to Flygvapnet fighter jocks: unlike the movieland pilots, they do not engage in acts of hero-making bravado over foreign lands. They are faced with an essentially fixed tactical situation in which their abilities may be tested only in rare, off-the-record combat, such as when a Viggen on a reconnaissance mission is jumped by Soviet interceptors over the Baltic and must wriggle free.

Indeed, the Flygvapnet's greatest challenge today may not be meeting the enemy in the skies over Sweden but just holding on to its own pilots. Until recently, an air force pilot made only about half what an airline pilot did. To stem the flow of pilots from the air force to the airlines, the government enacted a law in 1984 barring Swedish airlines from hiring more than 10 air force pilots a year. In 1986 the government coupled a considerable pay raise with a contract trainees sign indicating their intention to remain with the air force. In a further preventive strike, the government established the commercial pilot school at F5 to help meet the airlines' need for pilots.

Trainees drawn to a career in the air force cite some universal attractions. At F14, a technical training wing in Halmstad, young men and women talked about the appeal of a good job, security, some adventure, and an interesting life. Like the pilot trainees at F5, they were all former conscripts (except for the women, who make up five percent of the air force and who cannot be trained as fighter pilots), so they knew what they were getting into. Did they think of the pilots as an elite? "*They* think so," grinned one young cadet.

As does their fan club. After a week spent prowling the Flygvapnet's bases, the reasons for the admiration finally emerged. They may not be the obvious ones—the Swedes really do work hard to maintain neutrality—but they speak of the common bonds among military aviators.

Among those who know in the military aviation world, the word is out. There's no proof, it goes, that these guys can do it, or that they'll take the right side when they're required to abandon nonalignment in the fury of air combat. But in dozens of signals—in the contacts between Swedish and U.S. pilots at Edwards Air Force Base and the Patuxent River Naval Air Station, in the exchanges between engineers at General Electric and Volvo Flygmotor developing the engine for the Swedes' newest fighter, the JAS 39 Gripen—in all these kinds of interchanges, the word filters out. There is admiration of the Swedes' skill in the air, in building the airplanes, in maintaining them, in meeting every threat to their nation.

As Bengt Lönnbom says, "We can look anyone in the world in his or her eyes and say, 'We know that we are a good Swedish air force.' Of course, we are not a good NATO air force; we are not a good Warsaw Pact air force. But we are a good *Swedish* air force."

With luck, continued vigilance and the Viggens to back it up, neither Sweden nor any potential aggressor will have to find out what other kind of air force it might be. And the fan club can go on meeting in peaceful celebration.


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MCDONNELL DOUGLAS

Seasons, Seas, and Satellites

Oceanographers have expanded their scientific horizons with data collected from space.

by Frank Lowenstein

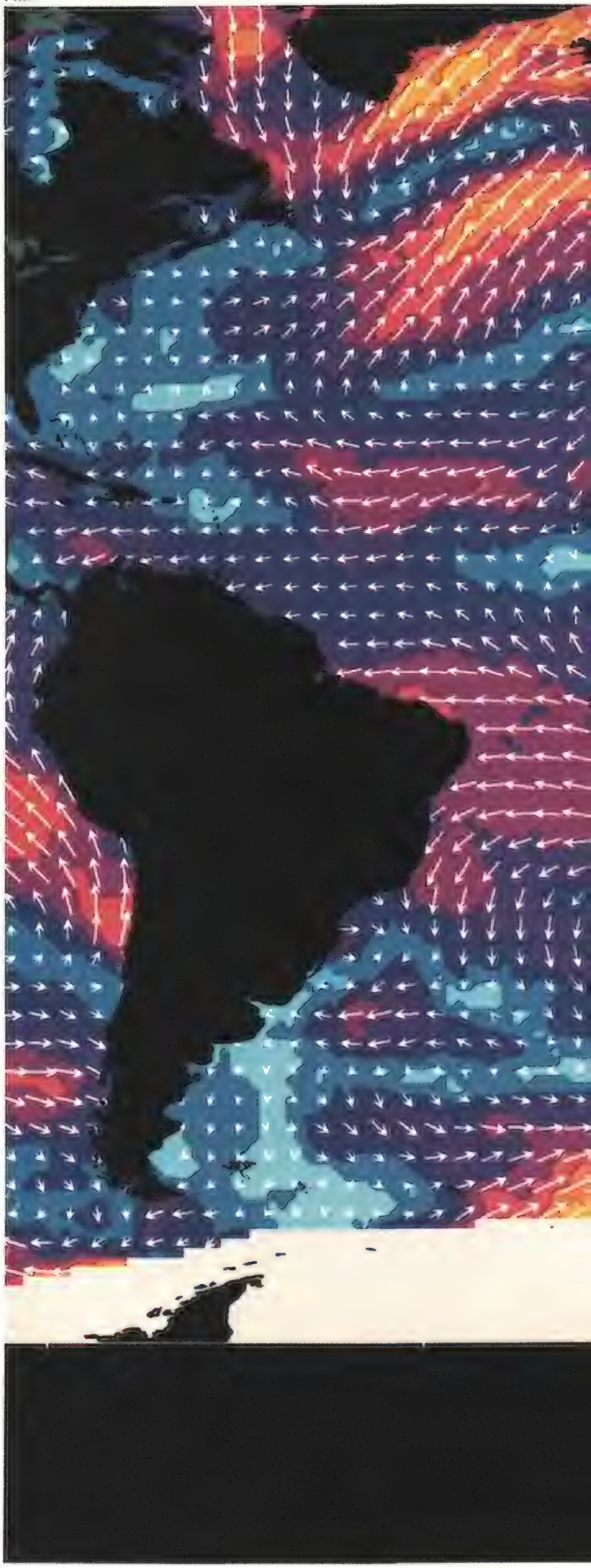
When Kathryn Kelly began studying the Pacific Ocean's California Current in 1979, oceanographers pictured it as an aquatic interstate off North America's west coast—wide and smooth, with only gradual changes in speed and few branch currents. But when Kelly looked at the satellite images on which she was to base her doctoral dissertation, she saw the equivalent of a mountain road—narrow and rough, intersected by jets of water curling out from the coast. Most of the oceanographers with whom she worked, she recalls, thought such a picture of the current "couldn't possibly be real."

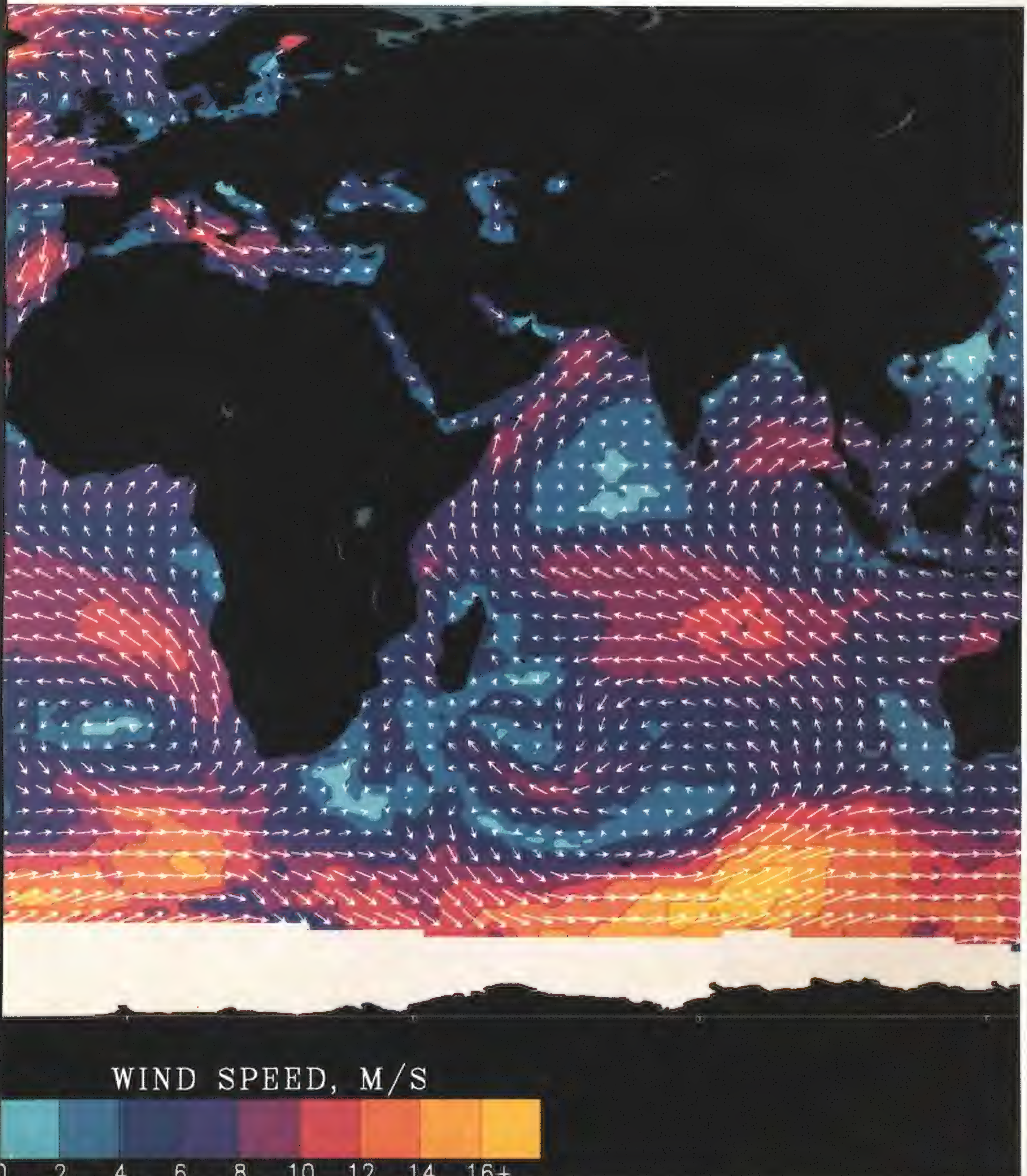
Kelly herself had doubts. As she stared at the twisting, mysterious lines on the satellite images, she says, "I kept thinking, *Where's the California Current?*" She even drew arrows on her photographs where she expected the current to be. But as she compared the satellite images to theoretical models and some puzzling data collected by ships at sea, Kelly became convinced that the satellite photos were showing something that oceanographers didn't know existed.

Two years later scientists using traditional oceanographic methods verified the existence of the small California coastal eddies that are now known as "squirts." The work of Kathryn Kelly—now an assistant scientist at Woods Hole Oceanographic Institution—was no longer on the fringes of oceanographic science.

In September 1978 NASA's Seasat used radar to take 350,000 wind measurements over the world's oceans. In a resulting map, arrows indicate wind direction; their length and color contouring signify speed. The intense winds southeast of Greenland are evidence of a fierce storm that drifted to the northeast during the three days of data collection. The dominant wind system over the Indian Ocean is the seasonal southwest monsoon, which carries oceanic moisture to Africa and Asia.

NASA




WIND SPEED, M/S
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Satellite imagery has revealed new features in the ocean, features that are too large and change too quickly to be detected easily from ships. Moreover, by providing vast amounts of data collected at regular, frequent intervals, satellites have allowed oceanographers to study already-known features in greater detail than previously possible. Today, says Robert Chase, formerly with Woods Hole and now a professor of aerospace engineering sciences at the University of Colorado at Boulder, "we're finding out every day that the ocean is not what we thought it was."

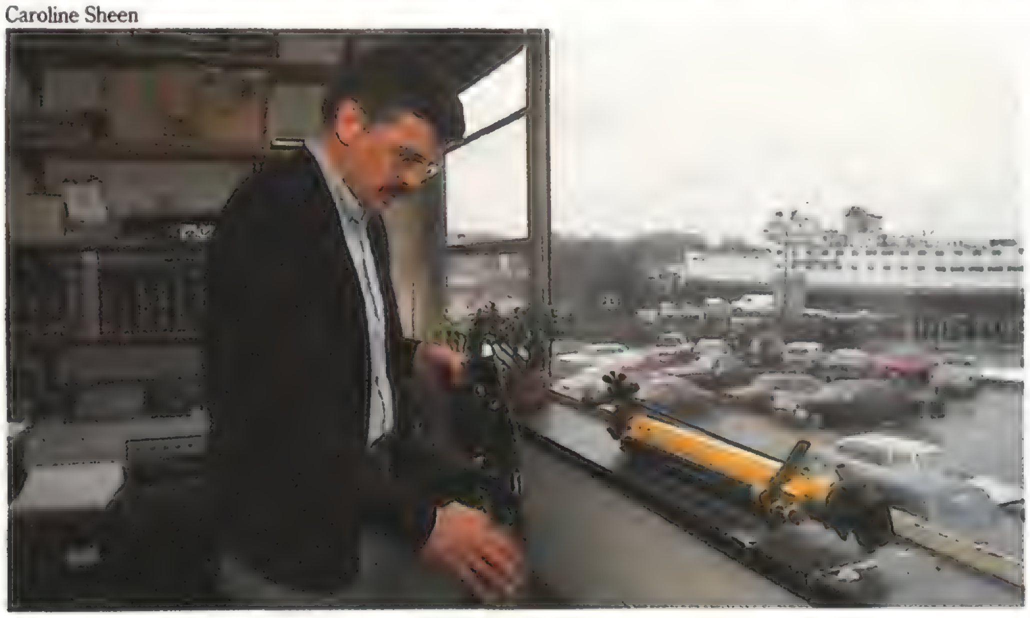
Oceanography isn't what it once was either. Even as satellites began playing a significant role, a trend developed within the discipline itself. While some oceanographers used satellites to further traditional studies of oceanic currents and the composition of the seas, others began a multidisciplinary examination of the roles oceans play in the ecology and climate of the entire earth.

For example, satellites are especially effective at discovering eddies. Vortices thrown off by currents large and small, eddies can be up to 200 miles in diameter and travel hundreds of miles over several years. From satellite studies, oceanographers now know that eddies help distribute nutrients throughout the ocean. The nutrients influence plant growth, which in turn affects the atmosphere's carbon dioxide balance. And by stirring up the seas, eddies speed up the dispersal of equatorial heat around the globe and thus affect winds and weather worldwide.

The techniques and equipment necessary to understand the global impact of the oceans are relatively new. When the institution at Woods Hole, the foremost research organization in its field, was founded in 1930, it had two major assets: its location at the end of a narrow peninsula on Cape Cod, Massachusetts, and its sail-powered research vessel, the *Atlantis* (for which the fourth space shuttle was named). These lean times gave rise to the stereotype of the "hairy-chested oceanographer out in heavy weather taking samples with a bucket," according to John Steele, Woods Hole's director. The science has since become more complex, but until recently oceanographers were still limited by the speed—rarely more than 12 knots—at which their research vessels traveled. Furthermore, regions such as the Antarctic were almost totally inaccessible. Ships were simply unable to collect enough data to allow scientists to understand the oceans that cover 71 percent of our planet's surface.

Oceanographers base their research on the conditions at "grid points," places where key parameters such as temperature and wind speed are regularly measured. "In the models we're using now, we have a few thousand grid points surrounding the globe," says Paul Wolff, assistant administrator for Ocean Services and Coastal Zone Management at the National Oceanic and Atmospheric Administration. But to understand the oceans well enough to determine their effect on climate, for example, will require 30,000 to 50,000 grid points scattered around the world,

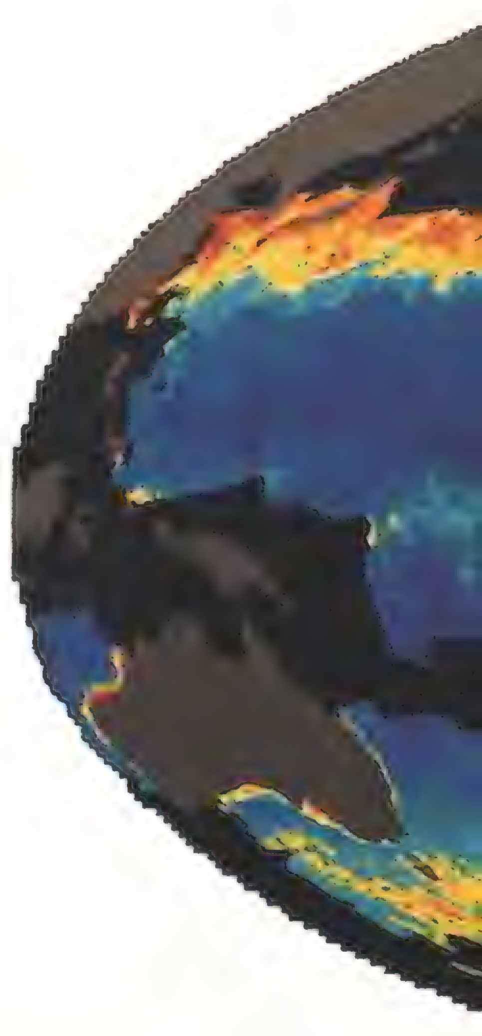
Caroline Sheen



Robert Chase filled his Woods Hole office with relics of seagoing oceanographic studies, including a Nansen bottle for collecting water samples (on the windowsill) and a Soviet current meter.

Caroline Sheen

One of the new breed of oceanographers, Kathryn Kelly spends less time at sea than she does in front of a computer screen, manipulating satellite imagery.



A composite of images from the Coastal Zone Color Scanner reveals that the highest concentrations of chlorophyll (red and yellow) generally hug continental coasts, while the lowest levels (blue) are found in midocean.

Wolff says. Understanding long-term climatic trends requires a better knowledge of the circulation of the oceans, the cycling of nutrients within the oceans, and the rate of growth of oceanic plants. Only satellites can gather much of the information necessary to understand these basic processes.

Meteorologists and astronomers caught on to the potential of satellites about a decade before the oceanographers. With oceanographic studies, going into space takes you farther from the action. "Once you get up high you have to learn to look through the atmosphere," says Stan Wilson, chief of NASA's Oceanic Processes Branch. "Once you do see through the atmosphere you're essentially only looking at the surface" of the oceans. That can be misleading. For example, satellites can measure sea-surface temperatures over large areas. But while temperature patterns observed at the surface generally extend several hundred feet below, sometimes they vary significantly from those just below the surface.

Despite their drawbacks and relatively recent acceptance, satellites have already contributed significantly to oceanographic knowledge. They have discovered uncharted polynyas, ice-free areas in the Arctic and Antarctic that scientists believe are important for the biological productivity of polar waters. No one knew of the existence of Antarctica's Weddell Sea polynya, which can be up to 100 miles long, until satellites spotted it in 1974.

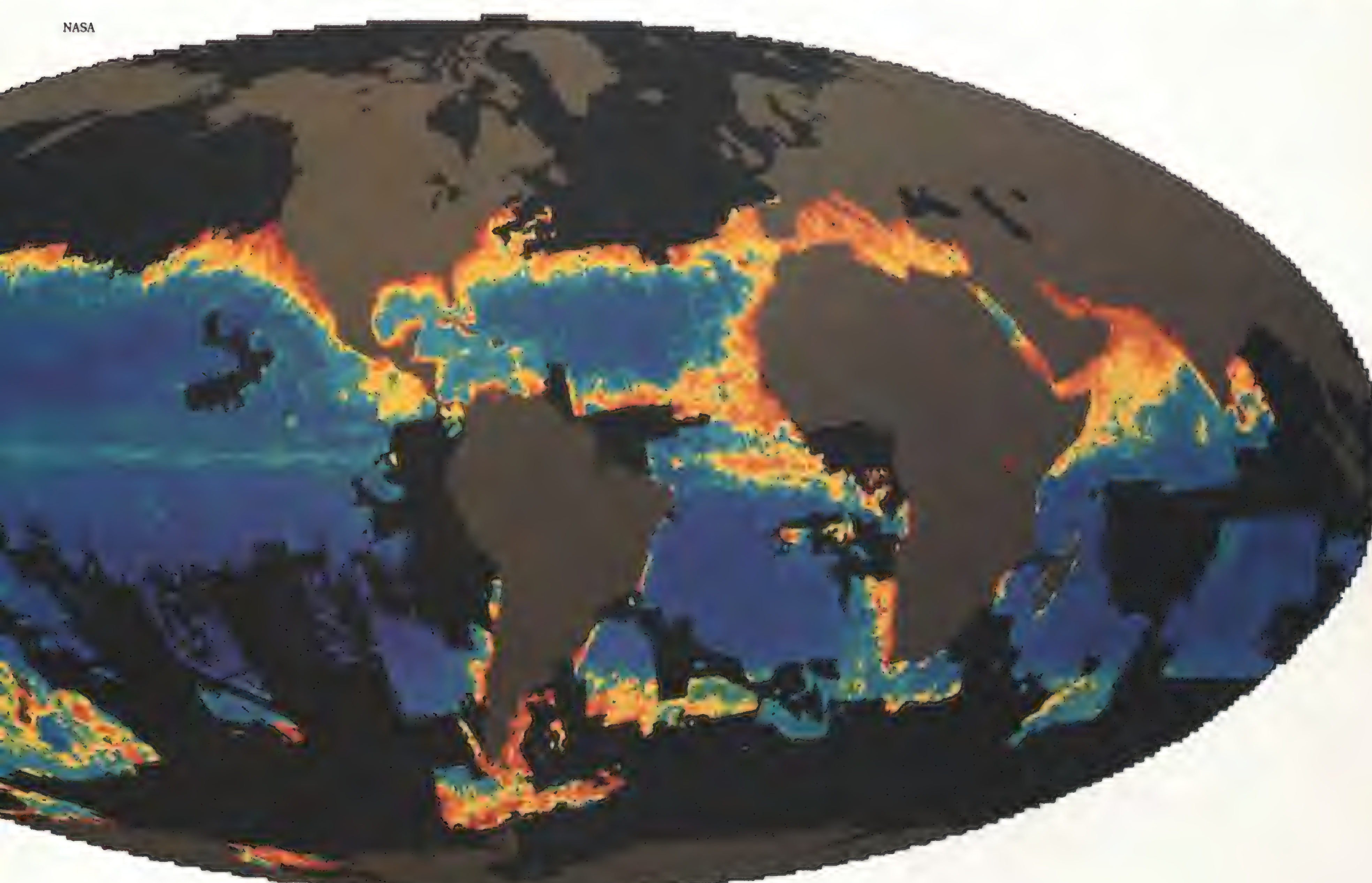
Off the coast of South Africa, satellites have been used to study the course of the Agulhas Current, which is so complex that over the course of about 150 miles, its flow often includes a nearly complete loop. Without satellites, notes Chase, tracing the movements of the Agulhas would require so many ships that it "would cost you the better part of the GNP."

Satellites have also given oceanographers insights into how their science interacts with climatology, biology, geography, and even political science, among other fields. Today, notes John Steele, "if you're an oceanographer, you're interested in desertification in Africa, mud slides in California, the wheat crop in the Midwest."

"Man is altering the planet," says James J. McCarthy, professor of biological oceanography at Harvard University. "We have altered the atmosphere. The greenhouse effect is real. The planet is warming. We don't know the consequences of these actions for what NASA has called 'the habitability of the planet.' "

The greenhouse effect, a global warming caused by increased levels of carbon dioxide and other gases in the atmosphere, could trigger climatic changes—a rise in sea level due to the melting of polar ice, greater rainfall in East Africa and the Sahara, and milder conditions in the Arctic and the wheat-growing regions of the Soviet Union. But few scientists are willing to speculate on how dramatic these changes will

NASA



Eyes on the Ocean

NASA

Precursor to Topex/Poseidon, Seasat studied ocean depth and circulation patterns.

To implement their global programs, oceanographers are looking to a series of satellites scheduled for launch in the early 1990s. A few replace older, less sophisticated satellites, but most will provide oceanographers with entirely new capabilities.

If the Pentagon approves its funding, the Navy Remote Ocean Sensing System could be the first of the new breed of oceanographic satellites to arrive in orbit. Its instruments will measure wind speed and direction at the ocean surface, wave height, the ocean surface's shape and temperature, the location of sea ice, and precipitation over the ocean. Much of this information is intended primarily for military use.

Oceanographers are particularly interested in measurements from a NASA "scatterometer" scheduled to fly aboard the Navy satellite. The scatterometer uses radar to measure very small waves, known as capillary waves, on the surface of the oceans. The waves, which are driven by local winds and vanish as soon as the winds die, are reliable indicators of wind speed and direction—key parameters in any model of ocean currents. At present, ocean surface wind speeds are known only at locations where ships or coastal buoys can take measurements. By using present satellites to track cloud movements, oceanographers can determine atmospheric wind speeds. From these observations, they can then extrapolate wind speeds at the ocean surface; such measurements, however, are notoriously imprecise.

Topex/Poseidon is a joint U.S.-French satellite scheduled for launch in December 1991 aboard an Ariane 4 rocket. Its satellite altimeter will be able to measure the shape of the ocean surface with radar. Knowing the ocean's shape helps oceanographers trace surface currents, which create differences of a few feet in surface height. Because variations in Earth's gravitational field create bumps and dips of up to several hundred feet in the ocean's surface height, oceanographers must first subtract the much larger gravity-induced variations. The Geopotential Research Mission, a pair of satellites that together would precisely measure the gravitational variations, is still in the conceptual stage at NASA.

In 1978 the Coastal Zone Color Scanner (CZCS) was launched on NASA's Nimbus-7. It was expected to operate for one year but continued to function until June 1986. In the 1960s, oceanographers on ships and airplanes had proven that the wavelengths of light reflected from the ocean surface are directly related to the local concentration of chlorophyll (which makes water greener) and that chlorophyll concentration is an accurate index of aquatic biological activity. Marine phytoplankton accounts for at least 30 percent of the Earth's photosynthesis activity, so tracking and understanding small sea plants is crucial to the development of a theory of the global carbon dioxide cycle. Experiments with the CZCS demonstrated the feasibility of studying phytoplankton with satellites.

Now scientists are eager to continue this research with a new color scanner. "The only way you can get [information on chlorophyll concentration] globally is from a satellite with an ocean color instrument," notes D. James Baker, president of Joint Oceanographic Institutions, Inc., a project planning and coordinating body directed by representatives of 10 U.S. oceanographic institutions. The most likely home for such an instrument is the Landsat 6 satellite, scheduled for launch in 1991. According to a spokesman for EOSAT, the satellite's operators, Landsat 6's color sensor has capabilities even more advanced than the CZCS's.

In early 1990 the European Space Agency plans to launch ERS-1 (for Earth Resources Satellite). It will carry both an altimeter and a synthetic aperture radar, which is especially useful for looking at sea ice. Two other satellites with synthetic aperture radars have been proposed: the Canadian Radarsat, which is still in the planning stages, and a Japanese Earth-monitoring satellite that may be launched as early as 1992.

By the turn of the century, these satellites, too, will need replacement, and already scientists are planning for the next generation of instruments and space platforms. Meanwhile, oceanographers' appreciation of the long-term measurements ocean satellites can provide is growing. University of Colorado professor Robert Chase is looking forward to the day when all the satellites now on the drawing boards are in orbit. If our understanding of the oceans and their role in global climate is ever to improve, says Chase, "the only way it's going to happen is by increasing the frequency and length of observations." And the only way that's going to happen is with satellites.

—Frank Lowenstein

be. "When climate starts to change, all bets are off," notes Richard Houghton, associate scientist at the Woods Hole Research Center.

One reason for the uncertainty is a fundamental lack of understanding of how carbon (including carbon dioxide), nitrogen, sulfur, phosphorus, and other elements are cycled through the environment. According to Houghton, today's best models cannot account for the movements of about 2.2 billion tons of carbon each year—more than is released by all the cars, power plants, and factories in the United States. Current estimates of how much carbon dioxide is removed from the atmosphere by oceanic processes may not apply once large-scale climatic changes begin.

Oceanic plants, like those everywhere, store carbon dioxide, but the seas can hoard it in other ways as well: gases continuously diffuse back and forth between the ocean and the atmosphere. When the ocean's surface waters cool and descend into the depths, they carry some gases into long-term storage with them. As a result, the deep oceans store about 60 times as much carbon as the atmosphere holds.

The oceans also directly affect the distribution of heat and moisture around the world. Winds drive ocean currents, which in turn warm or cool the air above them, generating new winds. The heat moved about by ocean currents moderates world climate, keeping equatorial regions habitable and preventing the poles from entering perpetual deep freeze. But "we lack real measures of the amount of heat carried poleward by the oceans," wrote Chase in an article he recently co-authored.

Satellites will provide useful new perspectives on oceanic plants, winds, and currents, but they can't do everything. Oceanographers maintain that ships will always be needed to confirm satellite measurements and look at oceanic processes that occur too deep in the ocean for satellite observations.

But even if the ships endure, Steele's hairy-chested oceanographer may become an anachronism. "The days when an oceanographer could do meaningful research by himself—that's sort of passé," Wolff says. "I see oceanography as a big science with big computer models." Big computer models require big computers and large groups of scientists working together, so Wolff expects the science to become concentrated at two or three institutions that can afford to finance such large-scale projects. Ships will become accessories to satellites, like puppets dangling at the end of heavenly strings.

Not all scientists are sure this view of oceanography is for the best. "There's still a hell of a lot we need to understand about the ocean itself," Steele says, though he admits that "to do both [large-scale satellite programs and extensive ship-based research] would require a doubling in the funding of ocean science."

Wolff notes that a lack of accurate models of the interaction between the ocean and the atmosphere "will soon become the biggest source of error in the two- or three-day weather predictions." Increasing the accuracy of those forecasts by even 15 percent would save several billion dollars annually in the United States.

But Chase is looking for even bigger payoffs from accurate long-term climate predictions. "If I can sit down and tell a farmer in Iowa that he's making a mistake planting winter wheat this year," he says, "the economic impact would be phenomenal. If you could tell people in the Sahel, 'You should not stay here because the Sahara Desert is going to take over . . . ' " For many oceanographers, this is the real promise of satellites.

Payson R. Stevens

Satellites provide the big picture, but oceanographers still use research vessels to get on-site measurements to compare with the data from space.

Get Away Special

NASA's smallest shuttle payloads fly standby, cost about the price of a used car to launch, and may be full of bugs.

by Linda Billings

Riletta Cream will probably never forget the day in 1977 when she met Irving Kessler. Cream, the principal of Camden High School in New Jersey, was looking for a way to interest her students in science, and she'd turned to the space program for inspiration. Kessler, an RCA executive, had a suggestion: the Get Away Special, a small, low-cost experiment contained in a canister that would ride the space shuttle. The students could design the experiment, and if NASA approved it for a flight, the students might grow as enthusiastic about science as Cream had hoped.

The Camden High students joined others from neighboring Woodrow Wilson High and together proposed an experiment in which a video camera would record how a colony of carpenter ants behaves in microgravity. The project was named Orbit '81. During the five years in which the ant experiment was designed and built, more than 300 students from the two schools participated. RCA paid the launch fee, donated some costly equipment, and provided a lot of advice. A South Jersey Chamber of Commerce foundation helped with money for the project, and a Temple University engineering professor donated his services as an advisor.

Word of the program began to spread. In 1982 astronaut Guion Bluford visited Camden High, and the local newspaper began following the project. Then the students shifted into high gear. They established an Orbit '81 newsletter, organized some special assemblies at school, wrote a song to commemorate the project, and even invented a project mascot—Tibor the alien, complete with a wardrobe made by the school's sewing classes. Vocational education classes turned out blueprints for the experiment and printed 2,000 press kits. The Orbit '81 project was ready for launch.

On June 18, 1983, it seemed as if the entire city of Camden was watching as the shuttle *Challenger* blasted off. And when it returned, all eyes were on the Camden High student who broke the seal on the Get Away Special canister and revealed that . . .

All the ants had died.

It was a colossal disappointment, but the students rallied and decided to mount an investigation. After a thorough scientific study, they concluded that the insects had died of dehydration

NASA

prior to being launched. It turned out that before every flight, Kennedy Space Center technicians routinely use dry air to purge shuttle payloads of moisture, which could condense on electronic equipment and cause short circuits. That was the end of the ants.

Orbit '81 outlived that first disappointment, though. The original science class project has turned into a continuing space education program. And during the summers, the Southern New Jersey Space Camp offers junior high school students a taste of space science, including one class on how to build—

Tag-along GAS canisters (lower left corner) return big dividends for such small packages.

what else?—a Get Away Special.

The Orbit '81 story captures the essence of NASA's program: with a well-designed experiment, anyone can carry out space research without fear of risking more than the $500 deposit to reserve a slot and a few thousand dollars for the launch fee. And NASA really does mean *anyone.*

With a $1.5 million annual budget, a full-time staff of six that occupies a few small rooms at NASA's Goddard Space Flight Center near Washington, D.C., and 495 reservations in hand from all over the world, the Get Away Special program is just about the only access ordinary people have to the space shuttle. Students, artists, scientists, small businesses, big aerospace companies, the armed services, even NASA researchers who can't get on the shuttle any other way have taken advantage of the opportunity.

The name "Get Away Special" was selected because it evokes a cheap escape to an exotic place. The experiments fly on a standby basis and must fit inside canisters that nestle in the nooks and crannies around larger payloads in the shuttle's cargo bay. NASA provides the aluminum canisters in two sizes: 2.5 and 5 cubic feet. Launch fees run from $3,000 or $5,000 for the small canister to $10,000 for the large one, which holds up to 200 pounds. The prices may seem steep for a ride into space, but the next-cheapest alternative, something called a Hitchhiker experiment, costs several million dollars.

The launch fee covers the services of an astronaut to turn experiments on and off with a small hand-held device that looks like a remote control for a television. Nobody has to take a spacewalk to flip a switch. Other services cost extra. Canisters carrying cameras to look out into space need a lid with a window, which costs $1,000. It's another $8,000 for a lid that will open up to expose the contents. A payload ejection device will cost even more, but it's not a standard option yet. So far, only two experiments have used the ejector.

The GAS can, as it's called, looks like an ordinary aluminum garbage can until it's been blanketed with insulation and plastered with decals just before flight. The experiments must pass rigorous NASA safety reviews even though the cans are sealed before launching. Customers can pack several experiments in one can, but experience seems to indicate that an experiment stands a better chance of working if it flies alone.

Get Away Special flight opportunities may suddenly materialize just weeks before a launch, sending customers into a mad dash to complete last-minute preparations. As soon as shuttle managers decide they can squeeze some experiments onto a flight manifest, NASA officials run down their list of flight-ready projects, trying to come up with a mix of U.S. government, private-sector, and foreign customers. In the course of 14 shuttle flights, NASA has launched 53 Get Away Specials containing about 100 experiments.

One of the latest additions to the reservation list was conceived in the People's Republic of China. Mark C. Lee, a U.S. citizen and NASA scientist who was born in China, met in 1985 with the Chinese Society of Astronautics to pro-

mote Get Away Special flight opportunities for students. The Chinese liked the idea and held a contest to solicit proposals from 150 million secondary school students. They got 7,000 entries and selected two winners. One will study the solidification of two nonmixable liquids in microgravity, and the other seeks a way to collect the annoying particles that float around in spacecraft cabins. There's also a backup project: a study of how cosmic rays affect Chinese herbal medicines.

Lee estimates that each of the Chinese experiments will cost $50,000 to build; the launch will cost another $10,000. The Chinese Society of Astronautics is building the experiments, and Lee has formed the American Association for the Promotion of Science in China to help raise money. Get Away Special program manager Larry Thomas reports that U.S. companies are competing for the chance to cosponsor the project. They're in it for an opportunity to make potentially lucrative connections with the Chinese, he explains, noting with a sigh that dozens of domestic Get Away Specials are going begging for sponsors.

But not in Utah. Perhaps it's because space education is emphasized in Utah's public schools, but whatever the reason, experiments and sponsors are unusually plentiful there. Gil Moore, a longtime employee of Morton Thiokol and a professor of physics at Utah State University in Logan, plunked down $500 of his own money for the first reservation when NASA announced the Get Away Special program in 1976—five years before the shuttle was ready to fly. Since then, Moore and his wife have donated $50,000 to Utah colleges for five Get Away Special experiments; two have already flown. The icing on the cake, he says, is to see some of the student experimenters go on to succeed in the space business.

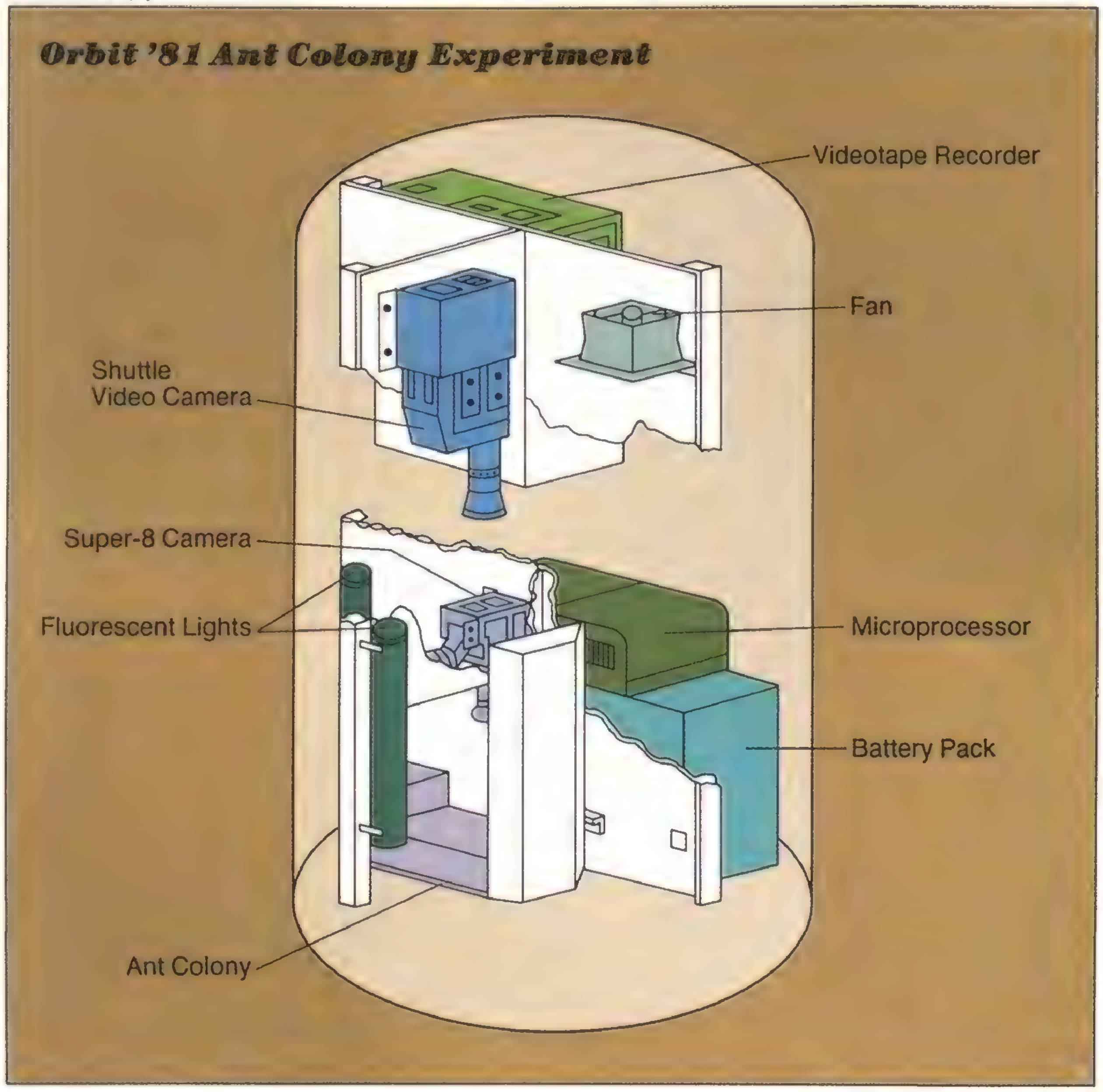
With guidance from Moore and from Rex Megill, who started working on Get Away Specials as a physics professor at Utah State, 25 experiments have made it into orbit. Megill supervised the Utah State students who developed the first GAS payload sent into space, in June 1982, and Moore paid the fees.

Megill left academia in 1987 to become president of Globesat, a new company headquartered at the Utah State University Research Park. The firm will build small satellites designed to be launched from Get Away Special canisters. They'll be larger than the first Get Away Special satellite, NUSAT (Northern Utah Satellite), launched into low Earth orbit on a 1985 shuttle mission. Under Megill's supervision, students from Utah State and Weber State College built NUSAT to measure signals from air traffic control radars. NUSAT II is already in the works.

Before he became a businessman, Megill designed the Get Away Special space pack, a hexagonal styrofoam container measuring 4 inches by 19 inches and coated with fiberglass and epoxy. It's designed to hold a single experiment and all of its support equipment, and a standard GAS can will hold up to six space packs. Once they have been sealed in their packs, experiments are safe and sound, but just to make sure, the experimenters subject them to the Rex Test—they put the packs on the floor and Rex Megill jumps on them.

Rex Ridenoure, a Get Away Special experimenter formerly with Utah State, calculates that 86 percent of school-sponsored experiments have failed because of various mechanical flaws, but only 18 percent of similar Get Away Special experiments developed by NASA or private companies have flopped. The school experimenters' record should improve, however, as they learn from others' mistakes.

J. Pinkston, M. Joy



Corporate customers have the resources to assemble more sophisticated packages. Edsyn Incorporated of Van Nuys, California, launched a Get Away Special in 1983 packed with nine soldering experiments, which the company said were intended "to determine if standard hand tools selected for space repair tasks would be able to withstand the rigors of outer space." The same year, the George W. Park Seed Company of Greenwood, South Carolina, launched a 25-pound payload filled with 40 varieties of fruit and vegetable

seeds. Park Seed researchers are studying how exposure to space affected the seeds, with the goal of developing packaging techniques for space station greenhouses.

Another agricultural experiment took off on NASA's last successful shuttle flight, 61-C. Launched on January 12, 1986, the orbiter carried a back-to-basics canister—no moving parts, no pop-up payloads, just a batch of bugs. The payload, developed by the U.S. Department of Agriculture's research center in Beltsville, Maryland, as part of a gypsy moth eradication program, was a four-pound package of thousands of gypsy moth larvae in diapause, a kind of hibernation. The larvae were laid out on canvas mesh to keep them from shifting around during flight, and they were accompanied by some cotton soaked in water to keep them from drying out.

Woodrow Wilson High School

The Orbit '81 project taught Camden students about teamwork and fundraising as well as science.

Get Away Special payloads often carry their own mission patches.

USDA researcher Neal Morgan says the experiment cost next to nothing—NASA donated the launch fee—and produced great results.

USDA researchers have been breeding sterile male moths in an effort to control the voracious pest. Female gypsy moths die after breeding, so infesting an area with sterile males at breeding time should wipe out the entire population. But the gypsy moth life cycle can take a full year, including six to nine months of diapause, and the USDA wants to produce its sterile males faster than that. Morgan reports that when the USDA experiment came back from space, larvae were emerging, although a control batch on the ground was still dormant. Exposure to space shortened diapause, but no one knows why. Regular launches of gypsy moth larvae into orbit could yield a year-round supply of sterile male moths. But that project will have to wait its turn.

Many experiment sponsors have put their projects on hold now that flights are harder to come by. Future shuttle flights will continue to offer spaces for GAS cans, and at least 14 Get Away Specials are ready to launch. But for the first few years after shuttle flights resume, the number of launches will be low. NASA stopped taking Get Away Special reservations after the shuttle accident, but will consider accepting them again once flights resume.

Some projects are moving full speed ahead anyway, propelled mainly by optimism. A project developed at North Carolina A&T State University in Greensboro should be ready to fly by the time the shuttle is ready. It includes two experiments—a study of how microgravity and cosmic radiation affect the mating and development of milkweed bugs, and a test of crystal growth in space. (The payload's logo depicts the school mascot, a bulldog, riding atop the shuttle.)

This project has been in the works since 1979, when physics professor Stuart Ahrens obtained a Get Away Special reservation to honor alumnus Ronald McNair, a NASA astronaut. McNair visited his alma mater several times after the project started up and met with students planning the experiments. "He was always as close as the telephone," Ahrens says. In 1984, the project team traveled to Kennedy Space Center to watch McNair's first shuttle launch.

McNair died in the *Challenger* accident of January 1986, and now more than ever the students view their work as a tribute to him. They plan to send his picture into orbit along with their experiments. They also want to engrave his name on their experimental payload.

The ultimate worth of the Get Away Special program will probably never be measured by the results of individual experiments. It's been 10 years since Riletta Cream, now retired, and Irving Kessler talked about a space program for students. Although the carpenter ants died, enrollment in various science classes at the two Camden, New Jersey high schools rose between 35 and 50 percent, and 60 percent of the Orbit '81 alumni went on to college. For them, the Get Away Special launched more than just an experiment.

The Hypersonic World of Robert Williams

It took political savvy, the gift of gab, and a solid knowledge of aerodynamics to get the National Aerospace Plane program off the ground.

by T.A. Heppenheimer

Katherine Lambert

Picture an aircraft, powered by air-breathing engines, that could fly from a runway into orbit. It's not a new idea—researchers in the United States have been working on the concept since the 1950s. But over the past five years, Robert Williams, manager of technology development at the National Aerospace Plane (NASP) office at the Defense Advanced Research Projects Agency, has been orchestrating the evolution of the space plane concept into a full-fledged government program.

Williams, 43, works out of DARPA's warren of cluttered offices in Arlington, Virginia, near the Pentagon. He is an energetic and highly successful advocate: with the help of many allies, he's been able to sell the aerospace plane program to a Secretary of Defense, the Air Force, the Strategic Defense Initia-

tive Organization, the Navy, NASA, the Congress, the White House, the media, and the public. Personable, articulate, and upbeat, he knows the ways of the Washington bureaucracy, the importance of defending one's turf, the conflicts between institutions and individuals. He keeps in touch with all the right people and knows how to move ideas through the political pipeline. He complains that he's spending three-quarters of his time on the road these days, sacrificing time that he'd rather devote to his children. But it's obvious that he likes his work and is happy to be on the move.

Williams is also an aerodynamics expert, with a bachelor's degree in engineering mechanics from Virginia Polytechnic Institute and graduate studies in acoustics and high-speed aerodynamics under his hat. After graduating from VPI in 1962 he became a program manager at the David Taylor Naval Ship Research and Development Center in the Washington suburbs. In 1975 he initiated work on the X-wing aircraft, a helicopter with rotors that could stop in midair and become a pair of large X-shaped wings. In 1982 Williams left the center to become a program manager at DARPA, the arm of the defense department that studies new developments in propulsion, aerodynamics, and exotic materials. Categorizing himself as a designer, he says his job is to talk with inventors, determine the potential of emerging technologies, and then find users to adopt them.

In 1982, Robert Cooper, then director of DARPA, decided to put some money into high-speed-flight research. Formerly head of NASA's Goddard Space Flight Center, Cooper had become interested in alternatives to rockets for spaceflight: at NASA, he had overseen some 40 Delta rocket launches, and he recalled that every one had revealed some potential for failure. He assigned the high-speed-flight work to Williams. "He was the right guy, he knew the most in this area, he was imaginative, he knew people in the industry," Cooper says. Williams proceeded with an idea for a Mach 8 missile powered by a supersonic combustion ramjet, or scramjet. He offered his idea to the Army and the Navy; neither was interested, but the work got Williams thinking about a scramjet-powered space plane that could fly into orbit. The prevailing opinion in the aerospace field was that a space plane would have to be powered by rockets, but Williams had something different—and more fuel efficient—in mind.

With a scramjet, once a flight was well under way, ambient air would flow into a carefully shaped inlet duct at supersonic speed. Liquid hydrogen injected into the air would be ignited to raise temperature and pressure and speed up the airflow. "With hydrogen as fuel you could go awfully fast," Williams says. "We hadn't encountered any upper limits." And while a rocket must take along its own oxidizer, a scramjet could use oxygen from the atmosphere.

In the 1960s, the U.S. Air Force had sponsored scramjet research by Antonio Ferri at General Applied Science Laboratories in Westbury, New York. NASA later built on Ferri's work, ground-testing two experimental scramjet engines as part of a hypersonic research engine program, with an eye toward testing a scramjet engine on an X-15 aircraft. But the X-15 program was canceled in 1968, and the scramjet engine languished in the lab for close to 15 years.

Williams began to pry the scramjet concept from the laboratory in late 1982. One day he gathered a group of inventors and consultants—he calls them "mavericks"—in his office to talk about a scramjet-powered aircraft. They started tossing questions around the table: How fast could you fly before the engine would burn up? How could you keep it from burning up? How low could you make the drag? How light could you make the structure? What was the right material? Then they went home to think.

In a few weeks Williams received a phone call from one of the mavericks, Anthony duPont. An unassuming designer who had developed and tested scramjets, duPont had a brilliant understanding of propulsion. While simulating hypersonic flight on his computer, he told Williams, he'd reached Mach 10, but his aircraft was hotter than the fires of hell. Williams drew on his knowledge of aerodynamics to suggest some design changes that would enable the aircraft to reach higher, cooler altitudes.

A few weeks later duPont phoned again. "I'm at Mach 16," he reported, "but it's getting awful hot again." Williams consulted his materials experts, who told him of products under development that might survive such conditions. The designer went back to work.

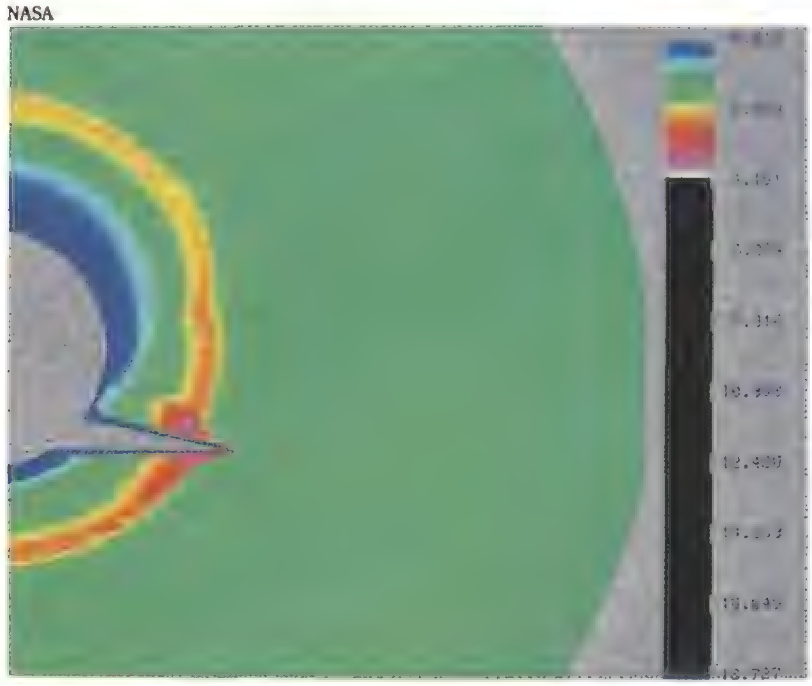
After several more weeks duPont made a late-night phone call to Williams. After two solid days and nights at his computer he'd pushed his aircraft to Mach 25. "We've just made history," Williams told him. "We've gone all the way, air-breathing, to orbit."

Williams asked his colleagues to dig deeply into the technical problems connected with this space plane. There were no contracts yet, but there's always a little money to be found in an agency's budget for exploratory work of this sort.

By early 1984, Williams had a design

Advocates and opponents come and go, but the space plane program has remained in Robert Williams' hands (left).

NASA



Space plane research depends heavily on computer simulations of hypersonic flight conditions. This simulation shows the different air densities around a space plane fuselage and wing.

for a scramjet-powered aircraft to take to his boss. "It was a very interesting concept," Cooper remembers, "but I questioned the assertion that they could make an airplane that would fly to orbit. They even believed it might be possible for it to re-enter the atmosphere, loiter for a while over an area of interest, then return to orbit. I asked them to go answer these questions, and I gave Bob some resources to do that." With this endorsement Williams could take his design to NASA and aerospace industry experts for a "sanity check," an independent review to turn up flaws. Williams began networking in earnest, turning up people who were willing to work on his space plane concept in their spare time and orchestrating the efforts of the growing crowd who wanted to enlist in the development campaign.

In the spring of 1984, with a substantial support group assembled, Williams went back to the boss. He was given only an hour on Good Friday for a detailed presentation, which he entitled "Resurrection of the Space Plane." It included 150 slides. "We blasted through them," Williams recalls, "then there was silence, and Cooper finally said, 'I want to spend a day on this.' That was our initial indication that he was seriously interested." Following a full-scale presentation by the entire group in June, Cooper agreed to put up $6 million for a classified study program tagged "Copper Canyon."

Through the summer of '84, as research proceeded, Williams took his message to aircraft and engine manufacturers around the country: "It's time to take space plane technology out of the lab and into the design room." One especially enthusiastic supporter Williams found was Paul Czysz of the McDonnell Douglas Corporation in St. Louis. While many of his colleagues in aeronautics believed that the next big step in commercial aviation would be an advanced supersonic passenger craft that could reach Mach 3, Czysz (pronounced "sizz") was aiming for Mach 6. At that speed, an "Orient Express" could cross the Pacific in two hours.

In December '84, Williams briefed then-White House science advisor George Keyworth on the space plane concept, and Keyworth quickly became a vocal backer. By early '85, Williams decided to push for a major program—development of full-size scramjet engines and an airframe to go with them. After attending a three-day meeting in March with the Copper Canyon researchers, Cooper asked Williams to start working on a budget and a program plan. No one could foresee how much the project would ultimately cost, but Williams and Cooper knew that DARPA could not finance the program alone. Cooper told Williams he would have to build a coalition of supporters at NASA and at Defense—NASA had an ongoing role in aeronautical research, and Defense had a big budget and an air force.

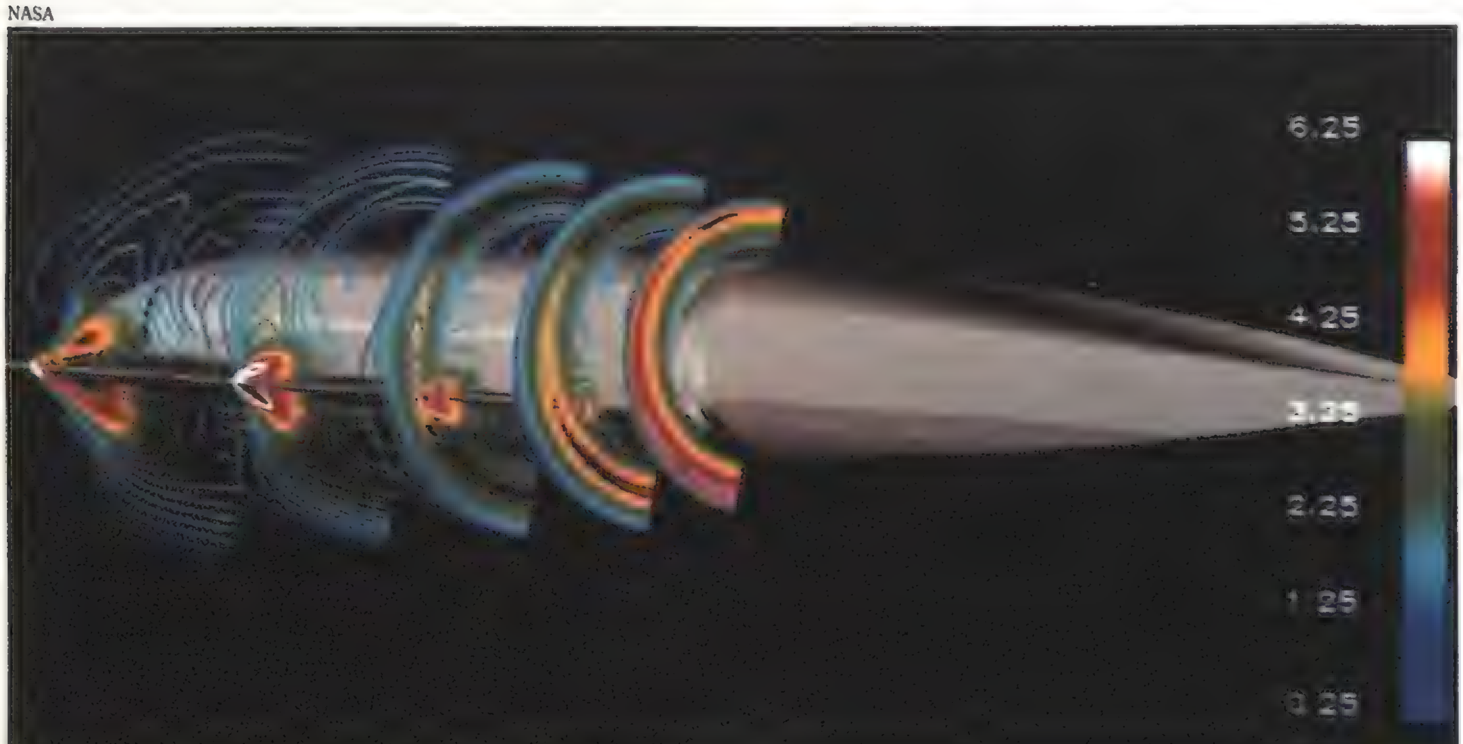
The key to winning Defense was winning over the Air Force, since a space plane would logically fall under its domain. Cooper arranged for Williams to meet with General Bernard Randolph, director of Air Force Research and Development, and General Lawrence Skantze, head of Air Force Systems Command.

Randolph quickly endorsed the initiative, and Skantze was equally enthusiastic: when he had headed the Air Force Aeronautical Systems Division, he had launched a study of transatmospheric vehicles—aircraft that could fly to orbit. Believing that powering space planes with rockets was not feasible, Skantze shared Williams' conviction that air-breathing engines were the way to propel such a vehicle.

Two weeks later, Skantze asked to see a firing test of a small scramjet engine under study at General Applied Science. Williams escorted him.

A young technician, excited over the visit from the four-star general, forgot to flip the igniter switch during the countdown. Before the technician realized his error and threw the switch, hydrogen fuel had poured into the engine. The resulting ignition was what is called a "hard start." The fuel detonated with a tremendous roar, sending the thrust gauge off the scale. Fortunately, the engine did not explode. Williams says he jumped about two feet, while Skantze watched on closed-circuit television in a control room, unruffled and impressed. As Williams recalls, the general remarked, "That engine sure does develop thrust, doesn't it?"

NASA



Researchers at NASA field centers have been simulating hypersonic flight on Cray and Cyber supercomputers. A simulation in an "ideal gas" environment—one that doesn't take into account chemical changes in the air caused by the space plane—maps the various pressures at intervals near the wing at Mach 25.

Pratt & Whitney

Leslie Bossinas for NASA

The space plane's scramjet engine will be subjected to extreme heat and stress, requiring new alloys of metals that won't mix under conventional processing conditions. Rapid solidification of titanium and aluminum in droplet form can produce a metal powder alloy that may be light and strong enough. Cooling takes place in one-millionth of a second in this new process (above).

No space plane will be unique for long. England, France, Germany, Japan, and the Soviet Union have their own designs, to be powered by ramjets or scramjets.

Williams next began lining up the right backers in the Pentagon in preparation for winning approval from then-Secretary of Defense Caspar Weinberger. In a week and a half, Williams and his associates met Air Force generals, the secretary of the Air Force, the heads of the Space Command and Strategic Air Command, the secretary of the Navy, and the head of the Strategic Defense Initiative Organization. General Skantze suggested a suitable name for the burgeoning effort, and it became known as the National Aerospace Plane Program.

Weinberger finally agreed to a briefing. Unfortunately for Williams, it fell on a day when the Secretary had just returned, jet-lagged, from a series of meetings in Europe. Undaunted, Williams arrived equipped with space plane models. During the briefing he grabbed a large blue and white model that was resting on the conference table and slid it down toward Weinberger. Staffers were alarmed, perhaps fearing that the Secretary would be impaled. Williams says he simply wanted to make sure that Weinberger got a good look. In any case, the Secretary must have been impressed: after the presentation he conferred with his staff and agreed that the program would proceed as a major Pentagon initiative, with Defense covering 80 percent of the $3.3 billion tab and NASA picking up the rest.

The groundwork done, Williams moved immediately to solicit bids for technology development contracts. At the White House, Williams talked with National Security Council officials and with the president's chief speechwriter. And when he gave his 1986 State of the Union address in early February, Reagan announced that the United States would go forward with a space plane research program that might lead to a new version of Czysz's hypersonic transport.

The National Aerospace Plane program itself will not produce a commercial hypersonic passenger transport. But it can develop the technologies required to produce an experimental aircraft—the X-30—that will be able to take off from a runway and fly into orbit. Variations of the X-30 could then be built for military or civilian missions, and industry could decide to use the technology for a commercial hypersonic transport. Since the spring of 1986, Pratt & Whitney and Rocketdyne have each won some $100 million in contracts to develop X-30 scramjet engines. McDonnell Aircraft, General Dynamics, and Rockwell-North American Aircraft have each won $32 million in contracts for airframe designs.

Williams hopes the X-30 will make its debut at California's Edwards Air Force Base by 1993, and he expects it to replace rocket-powered craft as the way to reach orbit with ease. But with the Reagan administration nearing its end, all of Williams' groundwork may have to be redone. With Reagan out, shifting political winds may topple the National Aerospace Plane budget. Williams is already working on the problem.

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NASA

In pursuit of better aircraft, designers are looking . . .

Into the Wind

by Victor D. Chase

As the test pilot climbed into the cockpit of the experimental Bell XV-3 tilt-rotor aircraft, his thoughts no doubt turned to the fate of its sister ship. During the maiden flight of the first "convertiplane," its pilot had attempted to shift the rotors from a horizontal position, where they functioned like helicopter blades, to a vertical position, where they worked like propellers. While making the transition the rotors became unstable, shaking the XV-3 so badly the pilot became disoriented. He was severely injured in the course of making an emergency landing.

The pilot of this second craft, however, had less cause for worry—his vehicle never left the ground. Rather, it performed its maneuvers while sitting in relative safety inside the test section of a mammoth low-speed wind tunnel. All went well: during several test runs engineers learned how to modify the design, and the conversion of an aircraft from helicopter to airplane was successfully accomplished.

Throughout the history of flight, wind tunnels have proven vital to aerodynamic research, staying, by necessity, several steps ahead of the aircraft. Even at what is commonly considered the beginning of modern aviation—the Wright brothers' first flights at Kitty Hawk in 1903—a wind tunnel came first. Two years before their *Flyer* left the ground, the Wrights designed a makeshift wind tunnel. Consisting largely of a square wooden box about four feet long, it and another tunnel the brothers built shortly thereafter provided the information on aerodynamic forces they needed to compare airfoil shapes and select the best configuration for the *Flyer.*

Wind tunnels, like aircraft, have changed considerably with the times. Today they can attain wind velocities over 20 times the speed of sound and can operate at thousands of degrees above zero or hundreds of degrees below. Designers of flying machines ranging from small general aviation craft to the space shuttle and its planned successor, the aerospace plane, rely on wind tunnels for safe and efficient testing. And tunnels

At NASA's Ames Research Center, the world's largest wind tunnel helps generate aviation's winds of change.

test more than aircraft. Automobiles, race cars, and trucks have all been put through wind tunnel tests so they can be made to slip through the air efficiently. Even stationary structures undergo the rigors of wind tunnel testing. Designers of large buildings, bridges, antennas, and the like often turn to tunnels to ensure that the structures can withstand the wind.

The tunnels are as varied as the objects tested inside them. Some blow hot and others cold. There are those that work slowly but steadily, while others work fast, in very short spurts. And some are much higher in pressure than others.

Even individual tunnels have changed over the years. The 40- by 80-foot giant at NASA's Ames Research Center at Moffett Field, California, has been transformed since it was used to test the XV-3 in the mid-1950s. Re-opened late last

Under an engineer's scrutiny, a model of the space shuttle undergoes testing to determine the effect of the external tank and boosters on its aerodynamics.

Charles Powell, AEDC

year after an infusion of $122.5 million, the tunnel boasts six 22,500-horsepower motors that can produce winds up to 345 mph. At the same time an even larger 80- by 120-foot tunnel was grafted onto the existing structure, allowing both to share the same power system. Known as the National Full-Scale Aerodynamics Complex, the huge joint structure is visible to the naked eye from low Earth orbit.

Because they are so varied, there is some debate as to which facilities actually qualify as wind tunnels. Donald Baals, now retired, spent his entire 35-year career at the seat of modern-day wind tunnel technology—NASA's Langley Research Center in Hampton, Virginia. "You don't want to ask anybody who spent his life in wind tunnels here how many wind tunnels there are at Langley," he says. "You'll get an answer anywhere from 15 to a couple of hundred."

Why the discrepancy? Sitting under stairwells and in corners of rooms throughout the NASA complex are "what we call research apparatus, which meet all the definitions of a wind tunnel but are very small," Baals says; "one may be in the corner of a room for a year, then disappear." Some purists also argue that engine test cells, much larger facilities for testing full-sized aircraft engines, are not true wind tunnels.

Semantics aside, wind tunnels come in two basic forms: continuous flow and intermittent flow. Continuous flow tunnels are usually closed loops with air flowing through them. They can operate for hours on end without taking a break. Intermittent flow facilities, on the other hand, produce short bursts of high-speed air. Sometimes operating for only milliseconds, they can attain airspeeds well into the hypersonic range—beginning around Mach 5, or five times the speed of sound.

In one type of intermittent facility, the blowdown tunnel, high-pressure gas is pumped into cylinders at one end of the tunnel while a vacuum is created in large spheres at the other end. As Baals explains, "You pump it up at one end of the line, suck it down at the other," and when the air is released, it can generate winds as fast as Mach 20.

In continuous flow tunnels, a fan or compressor placed in the flow path propels air around the circuit. Guide vanes direct the air around the tunnel's corners and curves. Just upstream of the test section, an enlarged area known as a settling chamber helps reduce turbulence. Typically, the settling chamber contains a series of mesh screens, some fine enough to hold water, to create a more uniform airflow in the test section.

In subsonic tunnels, the tunnel narrows just before the test section to boost airspeed. The rules change for supersonic tunnels, however, because air moving above the speed of sound expands faster than it accelerates. For air to go beyond Mach 1, then, the tunnel itself must widen as it enters the test section. Because the Mach number achieved is directly related to the proportions of the test section and the size of the tunnel leading to it, test sections in supersonic tunnels must be carefully designed to achieve the desired Mach number.

Increasing the air's velocity by allowing it to expand can create a chilling problem, however. Rapidly expanding air cools dramatically—sometimes to about −300 degrees Fahrenheit, at which point it can liquefy. To prevent this from happening and to create the intensely high temperatures that aircraft experience at supersonic and hypersonic speeds, heaters are frequently used to warm the tunnel air, sometimes to thousands of degrees.

While the Ames complex is large enough to test many real aircraft, most wind tunnels can only hold models a fraction of the size of the aircraft they represent. And what happens in tests on a small-scale model is not necessarily what will happen to a full-size aircraft in flight. But these critical differences can be largely resolved mathematically, thanks to the work of Osborne Reynolds.

Around the turn of the century, this English scientist developed a method of calculating fluid flow around an object: multiplying the size of the object by the speed and density of the air flowing over it. Dividing that product by the air's viscosity results in the number that bears Reynolds' name.

Because of the importance of his formula, it is impossible to talk shop with wind tunnel people without hearing "Reynolds number" mentioned frequently. The higher a model's Reynolds number, the closer its test results will approximate those of a full-scale airplane in flight. To increase a Reynolds number, aerodynamicists can increase the size of the test model,

Dale Glasgow

The Big Chill

NASA's four-year-old National Transonic Facility at the Langley Research Center in Hampton, Virginia, uses extremely cold nitrogen gas to test models of air- and spacecraft. Actually a tunnel within a tunnel, the NTF has an aluminum inner structure and an outer shell of stainless steel. This insulating design, like that of a gigantic Thermos bottle, allows the tunnel to operate at cryogenic temperatures as low as −250 degrees Fahrenheit. It is perhaps the most accurate wind tunnel in the world.

The tunnel's enormous dimensions seem otherworldly. The guide vanes that direct air around the curves in the tunnel dwarf a technician working inside it, and the nozzles used to inject the liquid nitrogen that vaporizes into gas resemble pulsating shower heads for a giant. The 130,000-horsepower electric motors that drive the tunnel's fans draw enough energy to power 2,000 homes.

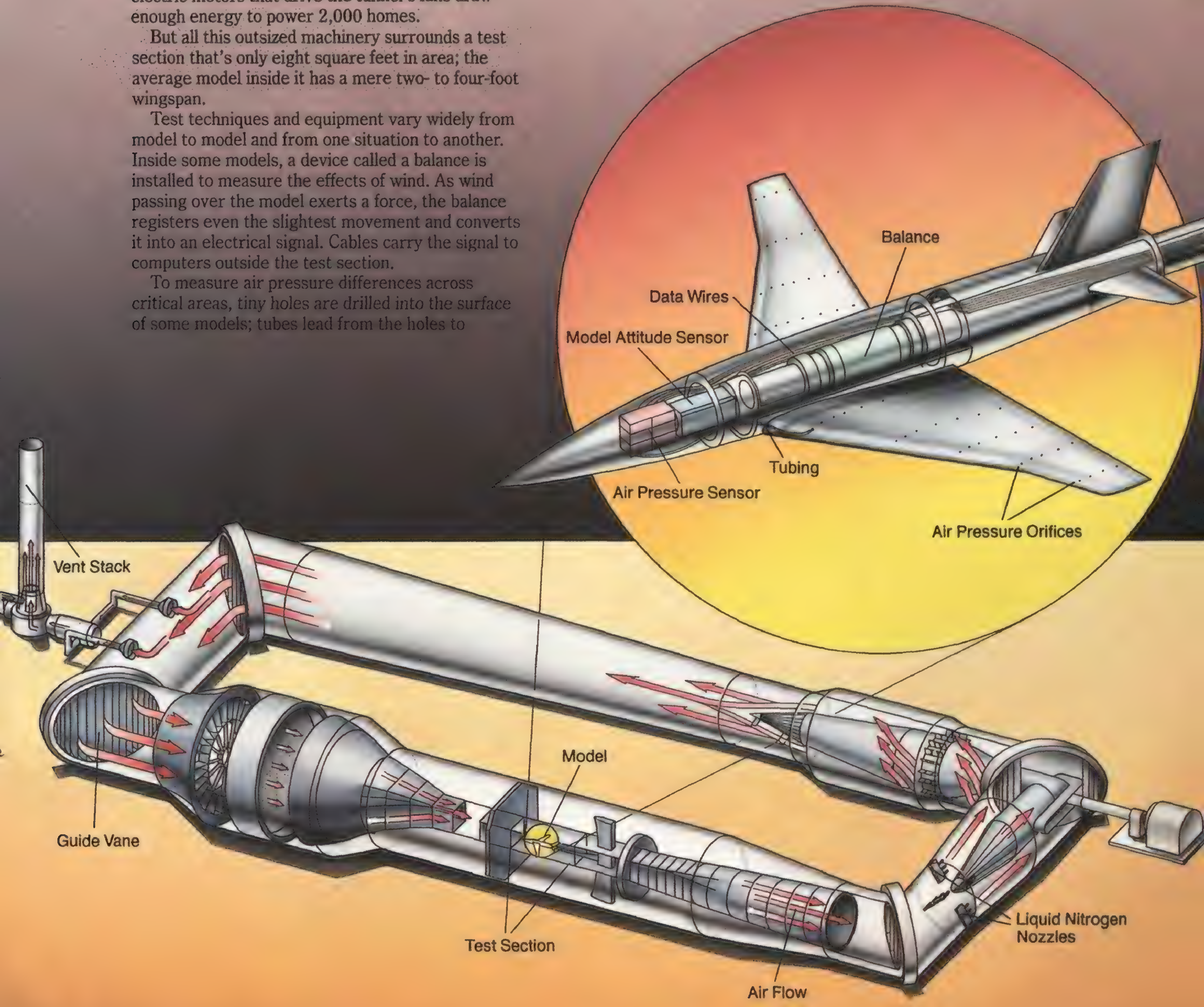
But all this outsized machinery surrounds a test section that's only eight square feet in area; the average model inside it has a mere two- to four-foot wingspan.

Test techniques and equipment vary widely from model to model and from one situation to another. Inside some models, a device called a balance is installed to measure the effects of wind. As wind passing over the model exerts a force, the balance registers even the slightest movement and converts it into an electrical signal. Cables carry the signal to computers outside the test section.

To measure air pressure differences across critical areas, tiny holes are drilled into the surface of some models; tubes lead from the holes to transducers, which translate the pressure into electrical signals.

The tunnel's extreme cold can produce unusual side effects. Blair Gloss, assistant head of operations at the NTF, recalls, "I was standing out in the parking lot one day and *plunk*, I heard a sound and saw a small piece of ice there on the ground. It was kind of interesting, on a sunny day, to see this piece of ice fall out of the sky." A bit of scientific investigation revealed that under certain weather conditions, nitrogen gas vented from the tunnel through an overhead stack causes moisture in the air to condense, creating hail. Under different conditions, the result is fog. This powerful, cold giant even creates its own weather.

—Victor D. Chase



Lee Battaglia

increase pressure in the tunnel, or decrease the tunnel's temperature.

Reynolds numbers are the stock-in-trade at NASA's Langley center, home of the National Transonic Facility—one of the newest wind tunnels in the world and, according to some, the best (see "The Big Chill," previous page). The transonic facility, with an operating temperature of around –250 degrees, is the world's coldest wind tunnel and consequently provides the best Reynolds numbers. It is regarded as something of a National Bureau of Standards for wind tunnels.

Another transonic tunnel, located at the Air Force's Arnold Engineering Development Center in Tennessee, has a purpose considerably different from providing accurate Reynolds numbers. This tunnel, with a four-foot-square test section, is used primarily for checking the performance of aircraft carrying external bombs and missiles. One important aspect of the testing is to ensure that ordnance will fall clear when it separates from the airplane. "Sometimes the bomb will fly back up against the airplane, and that's something the pilots get very upset at the engineer about," says Colonel Lowell Keel, who was director of technology at AEDC before he took up new duties at the Pentagon.

Several of the AEDC's facilities are capable of simulating Mach 16 to 18. Called arc facilities, they create a short-lived but very hot gas stream. A chamber in front of the test subject heats high-pressure gas by flashing an electric arc between two electrodes as the gas circulates around it. The hot gas stream then shoots through a nozzle and over the model. These facilities are used primarily to subject materials in missile nose cones or aircraft leading edges to the rigors of reentry into the atmosphere.

Another new AEDC complex, the Aeropropulsion Systems

A massive labyrinth of pipes cools exhaust gases and pumps them from an Air Force propulsion test facility.

By changing its dimensions, a supersonic tunnel's flexible nozzle can adjust air speed in the test section (below).

Phil Tarver, AEDC

Test Facility, tests aircraft engines. Here, full-scale engines are mounted and operated just as they would be in an aircraft. "We provide high-pressure air into the front of the engine and we pump off the exhaust behind the engine to make the engine think it's flying in an airplane," Keel explains.

One of the unique things about the facility, he adds, "is that we can vary the conditions while the engine is running. Many of the problems we see in flight [occur] not while the engine is sitting there droning at a given condition but when the conditions are changing." To duplicate flight conditions, huge refrigeration units and gas heaters allow the experimenters to rapidly change airflow around the engine from a frigid −100 degrees to a rather warm 1,200 degrees.

While much testing at AEDC involves models of entire aircraft, it is not uncommon at NASA installations, where the focus is on research and development, to find only sections of aircraft being tested. Such was the case recently in the eight-foot High Temperature Tunnel at Langley, where a few unimposing pieces of metal representing the belly and engine intake of the proposed aerospace plane were being exposed to a series of five-second blasts of 3,000-degree air at Mach 7.

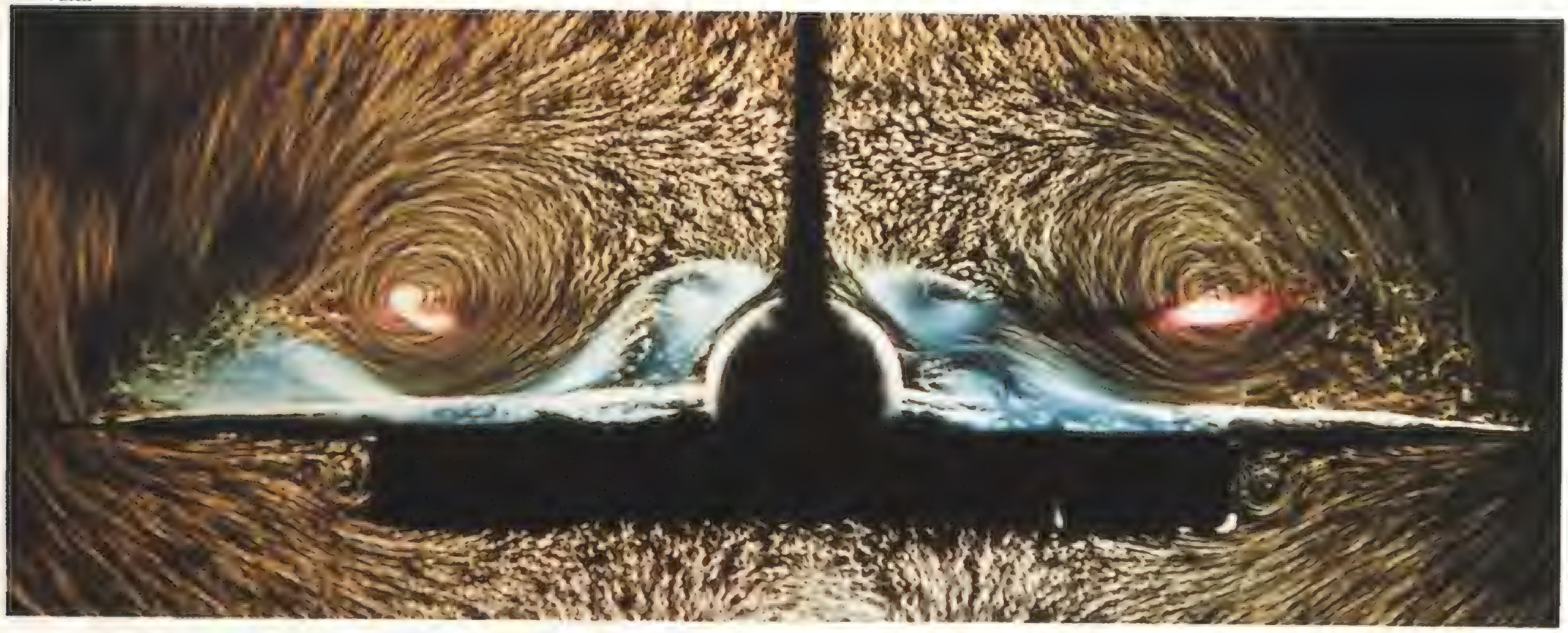
The aerospace plane will use air-breathing scramjet engines to push it beyond Mach 6 and nearer its goal of low Earth orbit (see "The Hypersonic World of Robert Williams," p. 52). At high speeds, the configuration of the underside of the aerospace plane and the shape of the engine intake both act to compress the air entering the engine. Engineers were using

Dyes injected in water reveal the whirlwind-like vortices that form at low speeds over a Concorde model's wings.

Laser light illuminates vortices on a model in NASA's Basic Aerodynamic Research Tunnel (bottom left).

A computer image from Air Force wind tunnel tests shows that a dropped bomb is likely to clear the airplane.

BAe Filton



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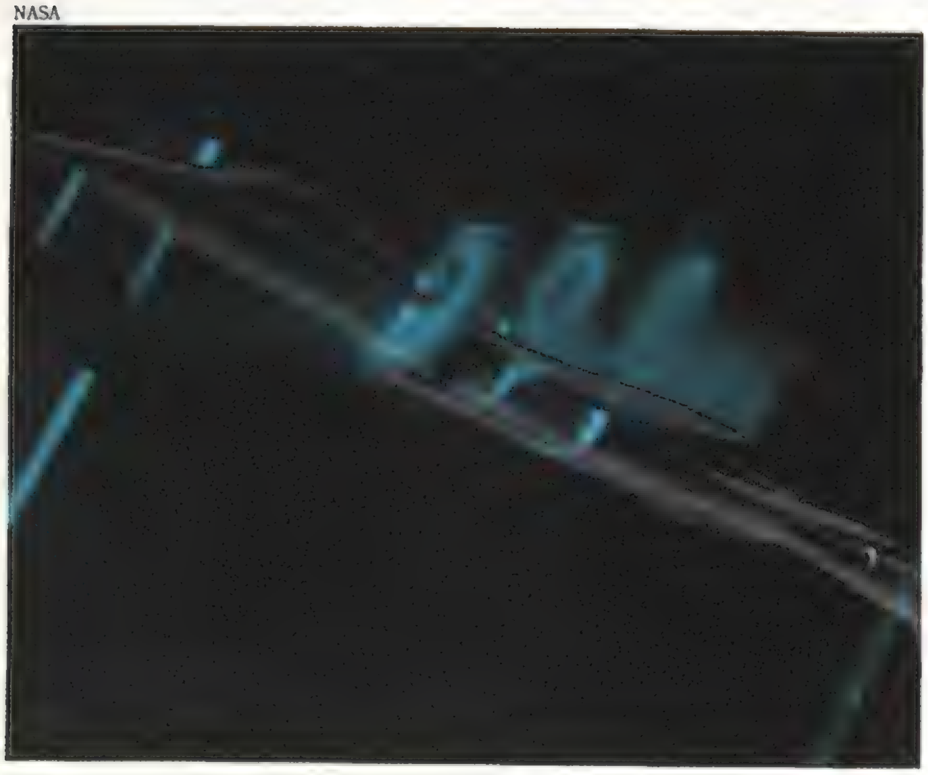

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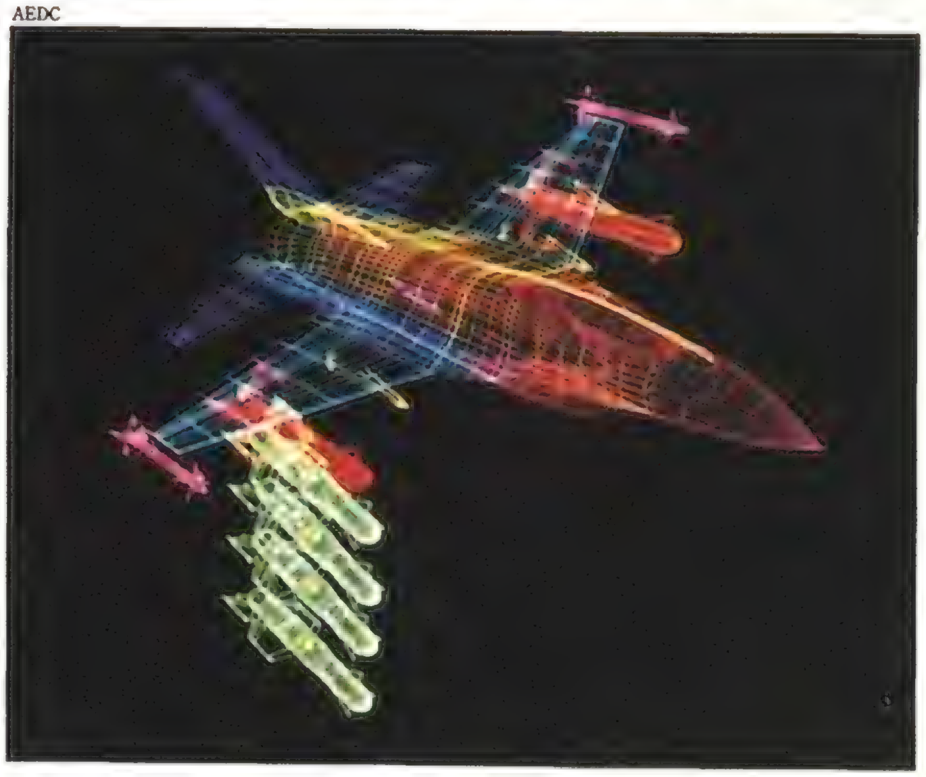


the tunnel tests to study the leading edge of the engine's metal covering. "Heating rates in this high-pressure area will be tremendous," explained Allan Wieting, manager of research in the tunnel. "Our measurements will help determine the optimum aerodynamic shape of the leading edge and what material and cooling concept will survive."

At the same time this apparatus was being put to the test, an inches-long model of the complete aerospace plane was being tested in the nearby Hypersonic Helium Tunnel, which can achieve speeds of up to Mach 20, though only for some 40 seconds. "We're measuring the performance, the stability, and the control, as well as the drag, the lift, and how it flies," said William Woods, head of the helium tunnel. A much larger model of the airplane, this one six feet long, returned early this year to the eight-foot tunnel, where it was tested for the first time for heating rates and air pressure over its entire surface, as well as for overall aerodynamic performance. Test results are now being analyzed.

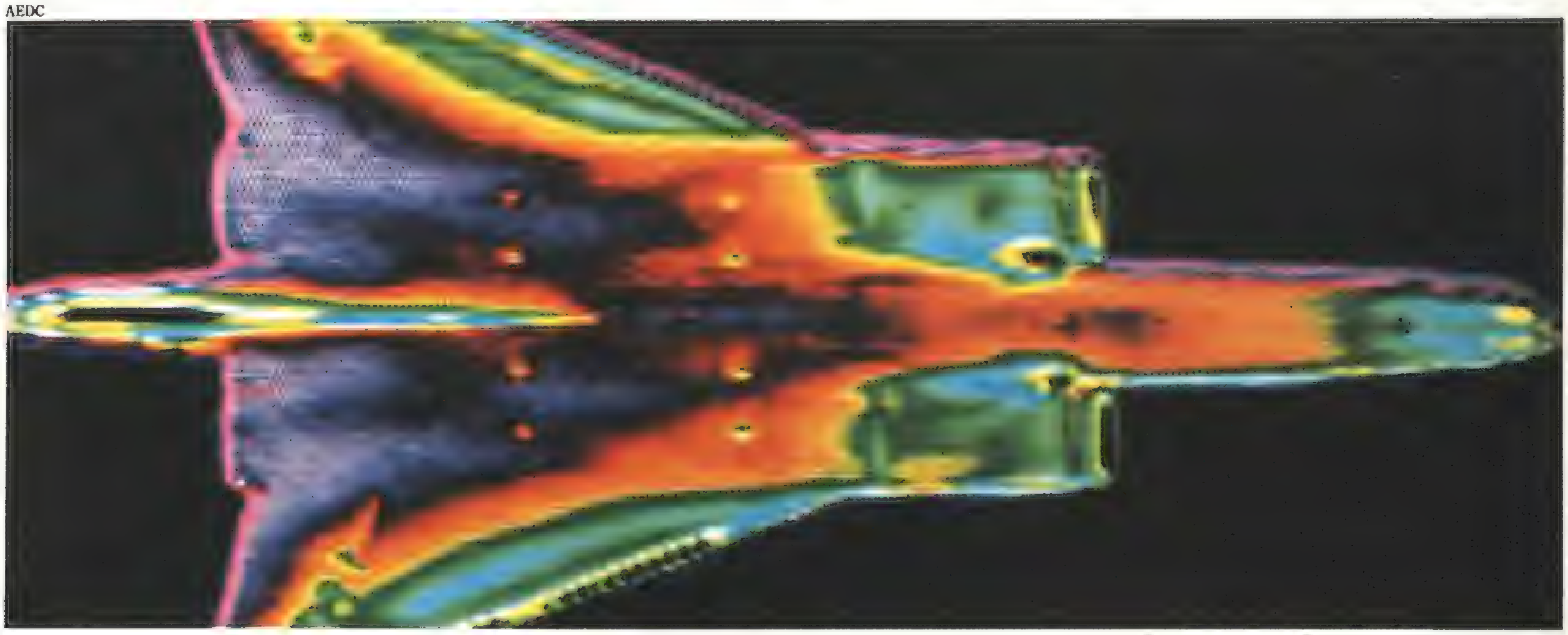
Those interested in testing their favorite model in a wind tunnel will find it a severe test of the pocketbook. The Boeing Commercial Aircraft Company's subsonic tunnel goes for \$500 to \$700 per hour, while the Lockheed Georgia Company's low-speed wind tunnel costs about \$1,500 per hour. Want something faster? Consider Boeing's transonic tunnel at

Heat-sensitive phosphorous paint on a model of a proposed fighter vividly reveals the range of temperatures resulting from varying air friction.

An electron beam in NASA's 22-inch helium tunnel shows the flow around a shuttle model undergoing testing for reentry at Mach 20 (bottom left).

Changes in gas density captured in a Schlieren photograph reveal shock wave patterns created as the shuttle's boosters separate from the orbiter.

AEDC



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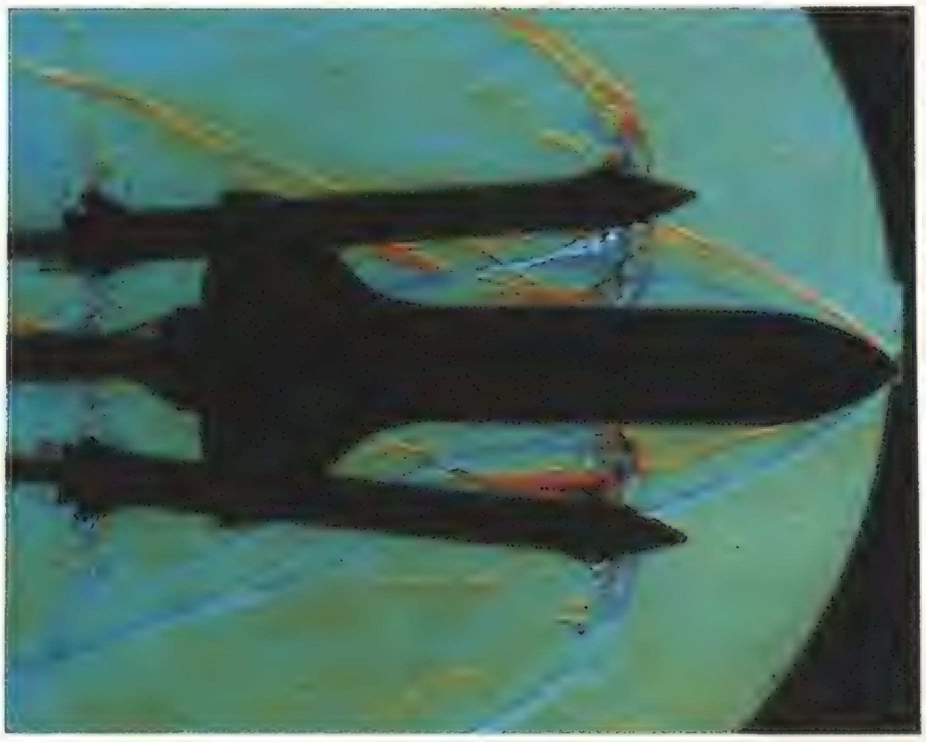

Sculptor in a Wind Tunnel

Like other heroes of aviation, Richard T. Whitcomb spent his career challenging the limits of nature, breaking new ground, and boldly defying precedent. But he did it all from within two eight-foot transonic wind tunnels at NASA's Langley Research Center in Hampton, Virginia.

Whitcomb, now 66 and retired, began working as an aerodynamicist at Langley during World War II. He achieved his success with methods that often seemed more like those of a sculptor than those of an engineer.

As conventional wisdom has it, when design problems arise with a given model, the engineer returns it to the shop for time-consuming remodeling. Having little patience with this process, Whitcomb would put models in a tunnel, find out what was wrong with them, and "then immediately starting with body putty," correct the problems. "In one day I can do what usually takes six months in the usual process, by just going in and filing on the model," he says.

Whitcomb's first major breakthrough using this approach was the Area Rule, which made supersonic flight a practical reality. Chuck Yeager piloted the X-1 through the sound barrier prior to the Area Rule innovation, but his rocket-propelled airplane broke the barrier with brute force. "That was not the way we were going to get production airplanes to go through the speed of sound," Whitcomb notes.

When an airplane breaks through the sound barrier, a shock wave forms in the air around it, causing buffeting, severe control problems, and large increases in drag—"All hell breaks loose," as Whitcomb puts it.

Aerodynamicists already knew of ways to cut the drag, such as thinning the wing down and sweeping it back, but "even with those changes the drag was still too high," Whitcomb says. He turned to the wind tunnel to find out why. "What I decided to do was study the basics of the problem: take Schlieren pictures [showing where shock waves form] and see what the air was actually doing."

One day in December 1951, as Whitcomb sat with his feet on his desk contemplating some wind tunnel photos he had taken, the idea came to him in what he calls a "eureka phenomenon." His theory was that the strength of a shock wave around an airplane is related to the total cross-sectional area of the airplane and the distribution of that area.

NASM

Richard Whitcomb's pinched-waist fuselage fooled the sound barrier.

"A smooth body has a low drag," he explains. Adding a wing obviously increases the drag. Taking this simple observation one vital step further, Whitcomb postulated that by indenting the body of the airplane he could compensate for the drag created by the wing. "If you take out the same amount of area the wing added, the area for the total airplane is now nice and smooth as if it were only the fuselage."

The next step was to go back to the tunnel. "We tested that wing-body combination with the identation in it," recalls Whitcomb, "and lo and behold, the drag for the total wing-body combination with the indentation was exactly the same as [that] for the body alone without the indentation."

Having paved the way for practical supersonic flight, Whitcomb turned his attention to wings—specifically, those of large transport airplanes such as airliners, which approach but do not exceed the speed of sound. Because air flowing over portions of the wing moves faster than the aircraft itself, shock waves develop on wings even before the aircraft reaches Mach 1. Whitcomb wanted to delay the onset of shock waves attacking the upper portion of the wings and thereby enable the aircraft to approach closer to Mach 1 before the adverse effects of high speed set in.

In the late 1960s Whitcomb blunted the wing's leading edge, flattened its upper surface, and curved its trailing edge down. The design, now known as the supercritical wing, worked. The shape allowed commercial jet aircraft to increase their top cruising speeds by about 10 percent.

In 1974 Whitcomb began to study the problem of vortices—powerful whirlwinds that form at wingtips and stream out for miles behind a large airplane, increasing drag and endangering other aircraft that fly into them. To break up the vortices, Whitcomb added small vertical "winglets" shaped like small wings to the wingtips. Wind tunnel tests confirmed that the winglets reduced the wings' drag and the strength of the vortices.

These innovations have brought Whitcomb wide recognition in aeronautical circles, but he is quick to share the credit for his success: "Without the tunnel," he says, "I wouldn't have done any of the things I did."

—Victor D. Chase

$2,500 to $3,200 per hour, or AEDC's four-foot transonic tunnel, sometimes rented out to friendly governments at an hourly rate of about $6,000. Considering that many tests take 100 to 150 hours, the bill for one test can easily run to $500,000. Sometimes the model alone costs that much.

If you can afford to wait, though, wind tunnel testing may be replaced by something much cheaper: the computer. Computational fluid dynamics, a kind of digital wind tunnel, uses mathematical models of airflow to duplicate what will happen to an aircraft in flight. For the foreseeable future, computers will play their greatest role in the earliest stages of design, with wind tunnel tests confirming their predictions.

"Usually what we do is sort through some configuration choices on the computer," says Keel, "and then do what I like to refer to as 'test smarter' "—reducing the number of expensive wind tunnel tests and saving them for last. "Frequently today, with two or three configurations we will be at the same point we would have been with 10 different configurations a number of years ago."

In fact, traditional wind tunnels are more in demand than ever. Where rental time is available, the wait is about two years. Whatever way the wind may blow, no one working in wind tunnels today seems concerned about losing his job to a computer.

A 1/50-scale shuttle orbiter weathers the icy blast of NASA's National Transonic Facility.

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ROCKETS FOR RAIN

In Yasothon, Thailand, a rowdy *Boon Bong Fai* is a plea for precipitation.

by John Hoskin *Photographs by Michael Freeman*

Rocketeers and revelers paint the town—and themselves—at Yasothon's annual spring festival.

It's hot. At 9:30 in the morning the glaring sun, already high in a near-cloudless sky, promises another day with temperatures in the 90s. You can't help wishing the heavens would open up with a cooling shower.

The light brown earth of the paddies is parched and baked hard from the long months of the dry season. Here in Thailand's economically depressed northeast region, a semi-arid plateau that supports only subsistence rice cultivation, it is easy to imagine farmers praying that rains come in time for the new planting.

And that's what they're doing. Each year near the middle of May, villages throughout the area hold a time-honored festival, staging elaborate rocket firing ceremonies to placate Phraya Thaen, the sky god, and to remind him of human needs. The biggest and best celebration is at Yasothon, a provincial capital of some 35,000 inhabitants located 360 miles northeast of Bangkok.

Yasothon's annual rocket festival is called *Boon Bong Fai,* which literally means "the merit of bamboo rockets." Most Thais are Buddhists, and the concept of religious merit, which is achieved by performing ceremonial deeds, is important in Buddhism. But Boon Bong Fai is also influenced by traces of ancient animism. Ritualized rocketry is used to appease the spirit world and reinforce the social and psychological structure of traditional rural life. Organized by local authorities and combining parade, contest, holiday celebration, and ritual, the rocket festival ties the themes of fertility, the generative forces of nature, sexual union, and rejuvenation into what is basically a rain-invoking ceremony.

These days, the people of Yasothon see Boon Bong Fai less as a religious rain-making ritual and more as a time for unbridled fun. As is the case with Mardi Gras and Carnival, the festival's purgative intent is fulfilled through ritualized license. Social norms are suspended, and drinking, flirting, and jesting are sanctioned for the occasion.

All the dancing and merrymaking revolves around the rocket, the festival's central motif. Yasothon rockets, the direct, if distant, forerunners of today's solid-fuel boosters, range from 4 to 13 feet long, excluding their tails. They are packed with up to 90 pounds of black powder to produce a burn time of 40 seconds or more. In the Middle Ages, when the ancient Chinese art of rocketry was exported to the West, these rockets would have been state-of-the-art.

On this sweltering Sunday the people of Yasothon are amassing at a little park on the edge of town. Some are mere spectators, out to enjoy one of the most eagerly awaited festivals in the regional calendar; others, mostly young men, are uninhibited revelers, wildly costumed and fantastically daubed with paint and mud. They dance and prance about in high spirits—literally, in many cases: bottles of potent rice whiskey are freely passed from hand to hand.

Some of these exuberant local lads carry very big homemade rockets. The

The final assembly, especially of a large rocket, depends on teamwork.

Rocket teams fuel their missiles with homemade charcoal, manufactured from specially selected local plants.

Hollowing out an exit for the rocket's exhaust gases takes a steady hand and an experienced touch.

largest has a 13-foot body and a 33-foot stabilizing tail, and six men are needed to bring it to a cluster of three rickety wooden launch platforms at the side of the park. Each platform is about 35 feet high and angled skyward at around 80 degrees.

For a moment, attention shifts to the clearing in front of the platforms, where a troupe of 60 or so colorfully attired young women begins a folk dance in honor of the sky god. Their slow, rhythmic movements are accompanied by drums, cymbals, and gongs.

Then the first rocket goes up with a deep roar and a trail of billowing smoke. It soars high and straight—a good omen in the eyes of the enthusiastic crowd. The rest of the day will be punctuated by the launching of rocket after rocket, just to make sure Phraya Thaen gets the message.

The day before, a parade down Yasothon's main street had featured 21 floats. The celebrants transformed utilitarian trucks into glorious chariots: a huge, lavishly stylized model rocket was the centerpiece of each float, while the truck's hood took the form of a *naga,* a mythical snake figure. Enormous cutout figures of characters from the *Ramakien,* Thailand's national epic, adorned each vehicle's sides. A few real rockets also made an appearance, accompanied by the young men who made them.

The parade wasn't scheduled to start until 12:30, but by early morning the ferris wheels on the fairground were running at capacity. Loudspeakers were blaring Thai music, and vendors were hawking fresh fruit, dried squid, and brightly colored iced drinks.

In the early afternoon, after the governor of Yasothon wound up his opening address, the fun began. Thirty or so *talai* rockets—bamboo hoops with rockets angled across the diameter—provided a spectacular start. About the size of Frisbees, the rockets are launched similarly, with a flick of the wrist. With exaggerated nonchalance a reveler would light the fuse with a cigarette, hold the hoop loosely until the very moment of ignition, then toss it away. Each rocket made a few horizontal spins before soaring to several hundred feet with a tremendous screech.

The parade started to roll. Floats alternated with groups of young dancers performing traditional local dances. Themes of agriculture, fishing, and rural pastimes predominated. Interspersed throughout were bands of pranksters, some riding on trucks with their own high-decibel sound systems, others mingling with the crowd. All were dressed outlandishly: one man wore a long red skirt with black trim and looked for all the world like a flamenco dancer; a tall, slim guy in cowboy gear coolly strutted about like some small-town Western sheriff; a blackened, half-naked warrior sucked on a tube that ran over his shoulder to a bottle of rice whiskey tucked in his hip pocket; and, prompting appreciative laughter from the crowd, a tubby fellow

Saturday's boisterous preview parade, with its theme of flight, sets the weekend's tone.

Perched precariously on the launch platform, team members put the finishing touches on their creation.

paraded about in green paint and a frog mask. Many splashed each other with paint or mud.

But for the rocketeers, the highlight of the weekend is Sunday's contest. The competition is divided into three size categories ("small" is defined as under six and a half feet in length and six inches in diameter). The prize money ranges from 2,000 to 10,000 Thai Baht (approximately $80 to $400), but that doesn't cover the cost of most rockets—a large missile will easily eat up 15,000 Baht and 20 days of painstaking teamwork. Everyone in the group chips in for expenses.

Rocket casings were originally made of bamboo stalks. In the last decade most contestants changed to metal pipe, which is strong and convenient—but dangerous if it explodes. In 1984 a bystander was killed by flying shrapnel from a metal rocket. Now the organizing authorities urge the use of plastic pipe. It's safer and lighter than metal, and rocketeers reinforce the interior with zinc sheeting and tightly bind the outside with cord or steel wire to limit fragmentation. Still, a few old-timers bemoan its relative weakness.

Even so, a plastic tube makes quite an effective rocket once it has been packed with fuel. The desired blend is 10 parts saltpeter, which acts as an oxidizer, and three parts carbon in the form of a homemade soft-wood charcoal. The saltpeter is dissolved in hot water before the carbon is added, and each batch is tested in rockets a few inches long before being put into service.

Team members pack the powder into their rockets a pound or so at a time, tamping it down with a wooden ramrod. The most difficult part of the procedure is boring a hollow central core through the powder for the exhaust gases. This job, performed with a pointed or corkscrew-tipped rod, requires an expert's touch. The core must narrow gradually toward the top and be perfectly straight, with no blockages or unduly wide cavities. Any mistakes will cause the rocket to explode on the launch pad.

The rockets may not be responsible for rain, but celebrants still have faith in the festivity's merits.

The top and bottom of the tube are then plugged with a mixture of clay and sugar—the latter acting as a binding agent—and capped with wooden plugs, which are bolted to the body. The rocketeers can now connect long, slow-burning fuses, sometimes with firecrackers attached, to the bottoms of their missiles. The fuses are made of rope or strips of saffron-colored cloth that look as if they were torn from the discarded robes of Buddhist monks. Maybe there is some propitious quality in this, though ignition failure is the most common problem at Boon Bong Fai. Finally, the rockets are fitted with long bamboo tails to stabilize their flight. These are attached about two-thirds of the way up the casing and bound at several points.

As the teams ready the rockets, making last-minute adjustments and re-affixing fuses, huddles of gamblers bet on the rockets' flights. In accordance with tradition, pranksters throw rocket makers into specially created mud pools.

The smaller rockets are set off first, and it is not until the afternoon that the few 13-foot monsters take to the air. One, two, sometimes all three launch pads are used at once, though the long erratic fuses prevent many simultaneous launches. With much swaggering—and staggering—the teams set up their rockets and, as in a game of chicken, the most drunken member usually lingers, clinging to the frame and leaping clear only seconds before the fuse catches.

A good rocket may reach 1,000 to 2,000 feet, but since the rockets carry no instrumentation for measuring altitude, the contest is judged on ground-to-ground flight time. The winning time is usually around 50 seconds; the record stands at 70 seconds.

The last rocket isn't launched until after five o'clock. On Sunday night, the roar of rockets still ringing in the revelers' ears, there are rains in the region.

GERONIMO!

A new sport has thrillseekers lining up to take a fall.

by Fred Reed

Photographs by Peter Menzel

The New River Gorge Bridge, on Route 19 in West Virginia, provides a spectacular view of green mountains rolling outward from the chasm where the New River runs, 876 giddy feet below. At 2 p.m. a man climbs onto the bridge's rail and teeters on the brink, to all appearances intending to jump. Wearing an outrageous red and green Hawaiian shirt and a beanie with a propeller, he looks like a tossed salad with a rotor. His right hand holds what seems at first glance to be a bouquet.

He does intend to jump, but not with the purpose of ending it all: the bouquet is a pilot chute, the rotor is a gag, and he is a BASE jumper, one of the curious clan who jump from high things like bridges for sport. BASE stands for Building, Antenna, Span (or bridge), and Earth (formation). Certified BASE jumpers are those who have made at least one jump from each. To date only about 180 people are certified, but the number seems to be growing rapidly.

About 200,000 people are watching the action taking place high above the New River. One side of the bridge has been closed off by the state police and is packed solid. This is Bridge Day, the one day a year when pedestrians can walk across the bridge and when BASE jumpers leap off it. About 400 of them are in the process of doing so.

Knees flexed, the salad yells, "I *love* this stu-u-u-u-u-fff," the last word trailing off into the depths as he falls through space, back arched, arms and legs spread-eagled for stability. He becomes a dot in three seconds of free-fall before, with a quick jerk of his wrist, he tosses the pilot chute, a small canopy attached to the main parachute by eight feet of cord. The aerodynamic version of a rip cord, the pilot chute grabs the air and snatches the main canopy from the jumper's pack.

From the bridge it looks as if the main chute isn't going to open in time, but at last a pretty square unfurls with the sound of a distant bedsheet flapping in the wind, and the jumper touches down on the sandbar landing site. Timing is important in bridge diving. You don't go very far or very fast in the first seconds, but things worsen rapidly thereafter. Actually the margin of safety is good—for most jumpers.

A view from a bridge: jumpers free-fall for three seconds, the first 70 feet of an 876-foot drop.

Once a year on Bridge Day in Fayette County, West Virginia, BASE jumping becomes a spectator sport.

Another jumper climbs onto the rail. Behind him stretches a long line of enthusiasts, checking one another's equipment while they wait their turns. Roughly every 20 seconds, another man or, occasionally, woman yells and springs into space. They have been doing it for hours. They will continue for more hours, some jumping four times.

BASE jumping is a relatively new sport. According to Jean Boenish, executive director of the United States BASE Association, sporadic and unorganized BASE-style jumps were made

Packing is important. When jumpers register for Bridge Day, BASE experts check their gear (left).

throughout the 1960s and '70s, but the sport really got its start in 1978, when four skydivers made a series of jumps from El Capitan, a 3,600-foot sheer cliff in California's Yosemite National Park.

The Yosemite experience taught the jumpers the best technique for launch: eyes on the horizon, knees flexed, arms spread, jump up and out. They experimented with other exits: one jumper rolled off on stilts; another increased momentum by riding over the edge on a skateboard. These approaches were judged unsatisfactory.

Although the press has sometimes made them out to be madmen on a lark, BASE jumpers are neither mad nor, judging by BASE jumping jargon, casual about their pastime. In a brief history of the sport published in the journal of the American Institute of Aeronautics and Astronautics, Boenish wrote that the El Capitan jumpers used "a state-of-the-art piggyback dual container system with the round reserve on the top and the square main below, tape-well or three-ring riser quick-releases, leg straps with B-12 snaps or thread-through enclosures, and standard 36-inch pocket-stowed pilot chutes." Not exactly casualwear.

The latest equipment is not standard skydiving gear but rather a version modified for faster deployment. A great deal of technical literature has been written on modifications for different altitudes and conditions. Velcro is used in packing parachutes to allow faster opening, with attention given to such niceties as the difference between its resistance to pulling as opposed to peeling. Square chutes are used more frequently than round ones because they can be guided more easily.

Look before—and as—you leap. Jumpers are warned to watch the horizon on launch (above).

Words can't describe the jumpers'-eye view, but a helmet camera can catch it—minus the ground rush.

Why do intelligent, well-adjusted adults jump off bridges? "It's different," says one . . .

. . . "It's a challenge," says another. "There's something more intimate about it, more immediate . . . "

In the early days BASE jumpers frequently jumped afoul of various branches of the establishment, such as the park officials at Yosemite and, later, the owners of buildings and the port authorities near bridges—"bureaucracies being generally unable to deal with the individual," as Jean Boenish puts it. After a brief period of cooperation, Yosemite administrators outlawed jumping. The USBA continues to negotiate with the park authorities, but as of this writing, those who are caught jumping from park cliffs are charged with a misdemeanor and fined $500.

Despite arrests and other obstacles, BASE jumpers persevered. Numbers grew. Techniques developed. There is talk that registration at the New River Gorge will have to be limited in the fu-

. . . "It's cheap," says a third. "The price of altitude keeps going up. You don't pay a pilot to get up a cliff."

After the burst of adrenaline, a BASE jumper swings into a waltz with nature. Rappellers descend allegro.

ture to prevent crowding.

What sort of people jump off a perfectly good bridge? To begin with, experienced skydivers. These aren't beginners. A few BASE jumpers are said to have worked their way from jumping off bridges to jumping out of airplanes, but most took the opposite route.

Further, they are both sociable and monotonously sane. They don't gesture wildly, hallucinate, or do much of anything out of the ordinary—except, of course, jump off bridges. They are pretty much the sort of folk you find scuba diving or racing sports cars—strong-willed, hardy individualists, inner-directed and, although few use the word, bored. Jumping off a bridge is one of the few ways they have of getting their own attention.

Most of them like to talk. Just off the bridge and around a bend, in a small park where the jumpers repacked their chutes, I introduced myself ("*Air & Space?* Neat. No kidding. Put me on the cover."), whereupon they started telling BASE stories, of which there are plenty. For example:

It is generally not legal to jump off antennas, so BASE folk tend to sneak up them early in the morning. It seems a pair of them were many hundreds of feet up one of these towers when the police, who had never heard of BASE jumping, showed up.

"Get off of there!" they yelled through a bullhorn.

Now, when you tell a BASE jumper to get off a tower, you get results. The police stared in horror at what they thought was an unusually awful double suicide. Doubtless they were imagining the response of the police psychiatrist ("You *told* them to do it?"). Then the chutes opened. The cops were so upset, said the storytellers, they forgot to ask for identification when they caught up with the jumpers on the ground.

More stories were swapped at the Ramada Inn in nearby Beckley, where the jumpers congregated after the Bridge Day festivities. Lean and fit-looking jumpers—none was fat—clustered at tables and watched the day's leaps on big-screen video. In the next room a convention of vacuum cleaner salesmen applauded their own heroes.

Several traits stand out among BASE jumpers. There were no blacks at Bridge Day. Whatever the reason, it is not discrimination: BASE jumpers welcome anyone who wants to leap from tall things. There were few women. Guesses ran from 4 to 12 percent. Although this is just an impression, many jumpers seemed to be from the professions and from technical fields.

Why do they do it? "Because jumping out of airplanes is boring," said Robin Heid, an engaging political consultant from Denver who attaches himself to reporters like a barnacle. "Same reason when you learn to ski well you want to try the expert slopes."

One woman said, "It's more exciting. You feel less pampered than in jumping from an airplane because you have less reserve altitude."

There are, of course, people who would not consider jumping from an airplane a satisfying form of pampering.

Most of the jumpers gave the same answers, although in different words. Some, like Jean Boenish, regard it as an aesthetic endeavor, more a communion

The only reward for hitting the target is dry feet. And there's no bonus for a bull's-eye.

These onlookers don't bother to chant "Jump!" BASE jumpers are inner-directed.

with nature than a quest for excitement. She calls it an "advancement away from dependence on aircraft toward the purer, more natural means of using fixed objects for altitude."

The Ramada Inn banquet room suddenly erupted with laughter. On the video screen a jumper sailed awkwardly from the bridge, perhaps having slipped as he jumped. You could see him rolling aimlessly around three axes, trying frantically to achieve a stable opening position. Maneuvering is difficult until you get up enough speed to provide air resistance, yet opening a chute while still spinning can lead to dangerous entanglements.

Finally the chute opened into a multicolored square. The crowd broke into mocking applause, the genial sarcasm of friends ribbing one another. "Get the man a static line!" "Lovely! Just lovely!"

Some might find laughter at such dangerous discomfiture heartless. It isn't, but rather evidence of a, well, robust way of looking at things. Had he been killed, nobody would have laughed. The victim was drinking beer at the next table, so they could afford to tease him.

How dangerous is BASE jumping, really? Very. Like mountain climbers and scuba divers, BASE jumpers depend for their lives on conscientious attention to equipment, on training, and on presence of mind. During last year's Bridge Day, at least one of these things failed 25-year-old Steven Gyrsting, whose pilot chute somehow fouled and didn't pull the main chute from his pack. While horrified jumpers screamed, "Pull! Pull!"—seeing instantly that the reserve chute was his only chance—Gyrsting fell to his death. His reserve chute opened, but not in time.

"In many of these accidents," says Boenish, who has studied the video of Gyrsting's last jump over and over, "we never really know precisely what happened." Boenish still isn't sure what happened when her husband Carl, one of the four pioneers who jumped from El Capitan and the founder of the USBA, was killed on a jump in Norway in 1984. Three days after Carl's death, Jean Boenish jumped from the same cliff.

The BASE jumping safety record, however, is good. The USBA attributes 14 fatalities to BASE jumping since 1978. Skydiving in general could be considered statistically safe. Of the 2.2 million jumps made in 1986, only 30 were fatal, according to the United States Parachute Association. The prevailing opinion in the Ramada Inn on Bridge Day was that as in other potentially hazardous sports, a high proportion of BASE jumping injuries involve inexperience, carelessness, or stupidity. There are accidents, but the careful seldom get hurt. One jumper quoted the old chestnut about there being old pilots and bold pilots, but no old, bold pilots.

BASE jumpers hate to make a splash, but rescue boats are on hand just in case they do.

Risk, of course, is part of the sport's attraction. Bob Mittig expressed the BASE attitude in his recounting of a close call he had. He and a partner had decided to jump while holding up a large skull-and-crossbones flag. (Around BASE jumpers, by no means all of the ham is in the eggs.) In the course of the jump, Mittig got turned around by the flag. To make matters worse, he had jumped with his slider up. A slider is a square cloth with a ring in each corner that slides down the lines of the chute as it opens, slowing deployment to reduce the opening shock. The additional fraction of a second is of no consequence when jumping from an airplane, but can be a problem in a bridge jump. In this case, the combined delays became alarming.

"My whole body felt electric," Mittig said, smiling peacefully and holding a beer. In the next room the vacuum cleaner salesmen applauded an unusual achievement in their field. "The ground rush was awesome. Everything got brighter."

People watching near the river estimated that he was only 20 feet from the water when his chute opened—a fraction of a second from what is known in the trade as a "bounce."

Would he keep jumping?

"Sure. These things happen. You can't let them affect your attitude."

Hardy individualist.

As with many people who enjoy danger but do not want to be killed, BASE jumpers are exceedingly careful. Jumping with a Nixon mask or a beanie may give an impression of playfulness, but it is a false impression. The pre-jump literature given to the jumpers heavily emphasizes safety. DON'T jump with gear you are not entirely familiar with. DON'T use various techniques that experience has proved unwise from bridges. Pack your chute with absolute care. If you jump slider-down, almost mandatory under 1,000 feet, be *sure* your equipment is in top-notch condition: the heavy opening shock might tear it apart.

Above all else, DON'T jump if you don't feel like jumping. A jump with almost no free-fall and very little reserve altitude is not a good time to go into brainlock.

When all is said and done, BASE jumping seems to be a response to some inner voice whispering a dare. Marta Empinotti, a young Brazilian, says she used to look at her apartment building back home and want to jump from it. She knew she couldn't, but she always kept it in mind. Finally, an experienced BASE jumper, she took the plunge she had been dreaming of.

"I loved it," she says contentedly.

ROUNDUP

In Australia's Outback, cowboys have traded their horses for helicopters.

Story and photographs by Kevin Murphy

Hovering among the pandanus trees, a pilot hustles to finish a muster before twilight.

Peter Underhill pipe-dreams while sweeping over the stark beauty that drew him to the Northern Territory.

Two helicopters lift off northern Australia's Arnhem Land scrub as the rising sun pokes through twisted ironbark eucalyptus trees. For cattle speculator Grahame Michell, who hired the Bell 47s and their pilots at $240 an hour, it is a day of reckoning. Three months in bush camp and thousands of dollars in supplies could be a total loss if the pilots don't drive any buffalo into the holding pen.

Months earlier Michell surveyed 250 square miles in the Northern Territory and found hundreds of wild cattle roaming the plains, gorges, and twisting riverbeds. He made a deal with the aboriginal landowners to split any profits he made in rounding up and selling their herds, and since then he's been carving out roads to truck in gear, and, with luck, truck out buffalo. He's erected a V-shaped trap and a huge steel pen to hold a thousand stamping, snorting animals. Now he has called in Heli-Muster and is hoping for the best.

Twelve years ago, John Weymouth bought a Bell 47 from a young and bankrupt mustering company and parlayed it into a multimillion-dollar business called Heli-Muster Limited, based at Victoria River Downs, one of the country's oldest and largest cattle stations. Since then, helicopters have largely replaced jackeroos—Australia's cowboys—in rounding up beef cattle. Teams of jackeroos working VRD once took an entire season—April to October—to round up and brand all the cattle roaming the station's 4,300 square miles. Now Heli-Muster does it by air in a few weeks, with 40 men, 25 helicopters, and seven twin-engine aircraft flying easily over terrain that hobbles the hardiest horses and distances that once made cattle management a hit-or-miss proposition. Mustering by helicopter costs up to $5 per head, but the total expense is less than the cost of keeping a team of skilled stockmen on hand. Before Weymouth revolutionized the ranching business, VRD employed up to a hundred stockmen. Now it's more like a dozen.

It's rumored that Weymouth can open paddock gates from his helicopter. He'll only say that anything you can do with a horse you can do with a chopper. He's logged more than 15,000 hours in helicopters—he started at age 16—and once mustered 7,000 cattle on his own in one day. Now, at 43, he closes business deals on the radio while chasing buffalo through the scrub.

As soon as the sky over Arnhem Land is bright enough, pilots Bob Green and Steve Kirkland start rounding up all the buffalo within a 10-mile radius of the portable pen. Bulls, cows, and calves are sent galloping toward the trap and eventual appointments with slaughterhouses or with cattle ships bound for Cuba and Southeast Asia.

While the Bells dither back and forth over the range, aboriginal stockmen doze in the sparse shade and in the cabs of steel-reinforced "bullcatcher" trucks. Of the crew of twenty or so waiting in the 100-degree heat, only Michell's wife Val doesn't nod off. "When we spend this kind of money I like to stay awake for it," she says, listening to the distant helicopters burning up profits.

In the air it's easy to spot the pen, hidden among frondy pandanus trees. From its entrance, two burlap wings angle more than half a mile into the scrub. The Bell pilots must herd the buffalo into the burlap trap, keep them from bursting through its flimsy walls, and funnel them through the six-foot opening to the pen. As the herds approach, tension mounts for the stockmen waiting on the ground and the pilots sweating in the plexiglass bubble of each chopper. No matter how skillfully they bring in the herd or split it to avoid overloading the pen, the pilots know they will be judged solely on the crucial seconds spent maneuvering the cattle through the bottleneck. Seven four-wheel-drive trucks are poised to swing in behind the thundering mob at the last second and prevent the cattle from backing out.

Hovering over a herd, Green finds himself pushing a tired mob of buffalo too far and too fast in too much heat. The night before, in a strategy session around a flickering fire, Michell said, "We'll take all the good luck that's going. It's the most important part of the equation." Green hopes Michell remembers his words at day's end.

Green and Kirkland finally have the mob at the mouth of the trap. Each peels back to bring up stragglers. They hover, then dive to 10 feet, spinning to raise dust storms—the only thing short of birdshot that moves old bulls. For hours they've been blasting their sirens and chasing determined loners while dodging gum trees and each other's rotor blades.

As the mob enters the V, Green looks for the truck ambush that will prevent the frenzied buffalo from crowding to one side or escaping from the pen. Without radios linking them, air and ground teams rely on a sixth sense to coordinate efforts to spring the trap.

But there are no trucks in sight. "Where are the damn bullcatchers?" Green yells over the radio to Kirkland. "Are they all still asleep?"

In the chaos of a muster, a pilot needs the instincts of a sheepdog and the flying skills of a Hollywood stunt pilot.

Epitomizing the term "bullheaded," a determined loner meets his match (below).

"They're moving in," Kirkland reports. The trucks come crashing through the scrub, dodging eucalypts and six-foot ant hills.

"About time," says Green. "Hey, on the left—they're crowding—they're going to break out!"

Helicopters wheel overhead, sirens wail, cattle bellow, men shout, horns honk. Two trucks, their drivers blinded by whirling clouds of sand, slam into each other. Worse still, the truck covering the outer left wing lags behind. Another in the center wheels hard left but runs over four buffalo and is stranded in a galloping sea of gray. Then the inevitable: a cow tears the burlap and 75 cattle break through and hightail it into the bush.

"Gone, dammit, gone," Green mutters. From the air the escape is obvious, but to those on the ground, still rubbing the dirt out of their eyes, it's mayhem. There will be some awkward lulls in tonight's dinner conversation.

Fortunately, about 500 buffalo are captured—possibly enough to turn a profit. Michell won't know until the cattle have been trucked out and recounted. The job done, Green and Kirkland leave the next morning. After sleeping in "swags" (bedrolls) and bathing in waters rife with "salties," bad-tempered estuarine crocodiles, they're anxious to get home.

The maintenance crew wages constant battle against the effects of Outback heat and dust on the aging Bell 47s.

Heli-Muster choppers work the entire Northern Territory and the northern half of Queensland, but VRD is home base. Because some of the Bells there are nearing 30 years of service, there's always at least one undergoing a complete rebuild. The Outback heat and sand continually test the mechanics' ingenuity—there are ongoing experiments with dust filters and cooling systems.

Thongs, shorts, and T-shirts belie the maintenance crews' professionalism. Fast and exacting repairs and service are vital to a business with narrow profit margins. With more than $2 million worth of spare parts handy, there are very few problems that can't be repaired in the field. New muster pilots—the "slaves"—spend a year in the hangar learning the intricacies of helicopter mechanics. "Even a great pilot will break us if we have to fly out to the bush for minor repairs he could make himself," says Weymouth. When a repair job is too big for a pilot, a mechanic is flown out from VRD. For most, it's a brief escape from station life.

Station cook Kim Borg loves the ranch's isolation, but she understands why many pilots last only a season or two. Married pilots, whose families live at VRD, have their own problems, but "it's pretty tough for the single guys," she says. "Even when women come here for a big weekend, the boys don't seem to know what to do or say."

There are barbecues, waterskiing on the Wickham River, and cricket matches that require all players to keep a beer in hand. Mail arrives twice a week, and TVs can pick up one station. But living more than three hours by truck from a sizeable town and working dawn to dusk seven days a week does not appeal to many. Money draws some—Jim Norrie, a former jackeroo, works as a slave "because until now all I ever owned was my swag." Though the hourly rate isn't great, there's not much to spend it on—Heli-Muster provides everything except the beer. And pilots can earn up to $40,000 a season.

"I get a pretty free rein out here—it's a real man's job in a real man's flying machine," says a veteran muster pilot. "Young fellows use this place for experience, to move on to bigger and better things. But they won't find it better anywhere else. We've got camaraderie and a family here, and it's because of that guy," he says, pointing to lanky John Weymouth.

"Got to keep 'em happy," says Weymouth, who's determined to maintain the family atmosphere at VRD: straight talk, generous bonuses in the end-of-season pay packets, a Christmas blowout at the Darwin casino. "It was a little closer in the past," he says. "The women would be nattering under the trees, waiting while the boys came in and the machines were put to bed. I want to get it back the way it was."

Weymouth still does his share of mustering, and when time allows he fishes for barramundi, hunts wild pigs and other menaces, and studies the aboriginal rock drawings he's discovered. Only an occasional mine, station, or homestead—Willeroo, Canfield, Banka Banka—interrupts the Northern Territory wilderness. "I fly over the same land every day and see something new every time. I'd rather do this work than anything else in the world. It's the ultimate occupation."

It's also one of the harshest. Men are injured in brush fires, killed by careening trucks and stampeding buffalo. One pilot died last spring when he flew into the ground at dusk while attempting to wrap up a difficult muster. "People have become very blasé about helicopters," says Green, a one-year Heli-Muster veteran. "They forget how dangerous it is. You have to push yourself and the machine to do the best job—and survive." With most Heli-Muster pilots flying nearly 800 hours a year and rounding up more than a million cattle, there's ample opportunity for mistakes. "I constantly have to keep myself in check and say, *Hey, there's no need for such a steep turn* or *You don't always have to fly between those trees,*" Green says. Besides self-control, a helimuster pilot needs top-notch flying skills, great concentration, patience, steely nerves, luck, and the ability to read a buffalo's mind. Only one in three pilots hired makes the grade. Many of them have worked as horseback stockmen, and like good sheepdogs, their success is partially due to instinct.

John Cunningham, Heli-Muster's assistant operations manager, is a seven-year veteran who doesn't miss newspapers and city life. "This isn't just a job—it's a lifestyle, and a good one at that."

Chief pilot Peter Underhill agrees. Beneath his chopper, which is painted like an American flag, a river meanders through a spectacular gorge. Garish parrots dot the trees like Christmas ornaments. Crocodiles loll in the late afternoon sun, eyeing the wallabies and kangaroos that sip at the water's edge. The taciturn Vietnam veteran with the scraggly beard sums up the attractions between puffs on his pipe. "I grew up in Northern California bush land. Now it's all suburbia. This is where the *real* freedom is."

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The Shuttle by the Bay

by Katie Janssen

Photographs by Kim A. Frazier

All Larry Kuznets needed from the Lawrence Hall of Science was a place to build a shuttle mockup. Just something temporary.

This is prime real estate, even by California standards. The view from the hillside is breathtaking: just below is the University of California's Berkeley campus; the San Francisco Bay and the city's skyline lie farther out; and beyond the Golden Gate you can see the Pacific.

The lucky occupant of this choice lot, the Lawrence Hall of Science, is a museum affiliated with the university. But since the spring of 1986, the Hall has shared its spectacular site with an unusual artifact: on a grassy knoll just behind the museum sits a full-scale mockup of the forward section of a space shuttle, its nose pointed toward the water as if the vehicle were outward bound.

Today the detailed replica is the centerpiece of a series of classes designed to introduce schoolchildren to the space program. But two years ago, when the administrators of the Lawrence Hall of Science loaned the site for the mockup to an energetic and charismatic teacher named Larry Kuznets, they were expecting a temporary exhibit. "We originally envisioned something very modest—made out of chicken wire, practically—maybe just the lower deck," recalls Kuznets. Only when the students in Kuznets' undergraduate physiology course had finished building it did they realize that the shuttle facsimile was far more detailed and complete than anyone had anticipated. "We have the entire crew compartment, the whole nose of the shuttle," Kuznets says. "We have a thousand tiles on the outside. We have all the computers and all the software that you'd find on the shuttle. All the computers and all the simulators work."

Blueprints helped, but NASA veteran Larry Kuznets could almost have laid out Berkeley's shuttle from memory.

Reluctant to dismantle the fruit of their labors, Kuznets and his students asked the museum administrators to make the mockup a permanent exhibit. The administrators, taken aback by the request, turned it down. If not for Larry Kuznets' intense devotion to his cause, that might have been the end of the shuttle by the bay.

Kuznets, who has the lean, Western look of a latter-day cowboy, had worked for NASA as a bioengineer on the shuttle and other programs for 17 years before returning to the University of California at Berkeley, his alma mater, to teach a course entitled "Life in Space." He was to present lectures twice a week, many of which would be given by scientists and policy makers from various NASA centers and Rockwell International, a NASA contractor. The physiology department projected an enrollment of a few dozen students at most. But after word of the course got around, 400 showed up.

On January 27, 1986, the spring semester had barely gotten under way. The class lecture on spacecraft propulsion systems included descriptions of the shuttle's O-ring seals and external tanks. The next day the *Challenger* exploded. For the students, whose lecture notes had suddenly become the stuff of headlines, the disaster had an almost personal impact.

Originally pointed at the Lawrence Hall of Science, the mockup was later rotated to face the Pacific.

Kuznets had his own crisis on his hands: many of his guest lecturers had to participate in post-*Challenger* inquiries and investigations. One by one, they canceled their lectures. Kuznets and his students spent the next several days wondering how to proceed and groping for some gesture that would help them vent their feelings. "I decided we could do a group project," he says. "And then gradually the idea evolved to build a mockup."

Kuznets resolved to teach something about aerospace management techniques in the process. He started by applying an organizational technique called a "work breakdown structure," in which responsibilities are diagrammed and roles assigned. The top posts—chief engineer, assistant chief engineer, and chief of procurement—were filled through class elections, and the remainder assigned by lot. The class also employed systems engineering to draw up a work schedule that included all the formal design reviews actually used in aerospace work.

Frank Porto, a mechanical engineer

for the Department of Defense who later served as a go-between when tension mounted between Kuznets and the Hall, thinks the organizational and scheduling structures were an important part of the students' experience. "They didn't just build a model," says Porto. "They have a unique conception of what it takes to work together and produce something substantive. It's been estimated that for a corporation to reproduce this would take a half a million dollars." That estimate is based on Kuznets' experience with other mockups; Porto says he thinks it may even be low.

The students launched their project with a much lower budget: each member of the class kicked in $5. They began by building small-scale models of various parts of the shuttle, basing their work on sketches and cutouts from the *The Space Shuttle Operator's Manual* by NASA veteran Kerry Joels. Meanwhile, Kuznets got hold of full-scale blueprints from Rockwell, and it was from these that the mockup was built.

Once Kuznets had obtained the blueprints and the students had acquired a sense of what they were capable of doing, the project grew like Topsy. The group leveled a patch of ground, built a wooden skeleton, then set to work constructing an accurate exterior and innards. Local businesses donated electrical switches, wire, lumber, and tools, as well as hundreds of bathroom tiles to replicate the heat shield. NASA sent several genuine shuttle tiles, a sample meal tray, and lots of advice. Sometime during the spring of '86, the goal of building a flimsy, temporary display changed to one of constructing a permanent, realistic monument.

But even a few hundred dedicated students can accomplish only so much in a single semester. By June a skeletal structure was in place, but most of the interior and virtually all of the detailing and finishing work remained. A small group worked through the summer, but by fall it had dwindled to fewer than half a dozen, including Kuznets.

Former student Stephen delCardayré was one of the most actively involved. "The purpose of the whole [*Challenger*] flight was education," he says. "The effect of the flight could have been very discouraging to a lot of young students interested in space .... [The mockup] was continuing the goal of the flight in a different way. With Larry a lot of it was the same feelings I had, and a lot of it was proving a point. It became a passion for him."

That passion led to friction with the Lawrence Hall of Science. As something permanent began evolving, almost literally at the museum's doorstep, relations between the Hall and the students became strained. "There was no graceful contact between us at that time," recalls delCardayré. At one point, the students were prevented from using the museum's bathrooms.

As is often the case with long-simmering antagonisms, it is impossible to say what first sparked the resentment, but the most important elements of the conflict were rooted in a simple clash of cultures. "I don't want to seem critical of either Larry or the Hall," says Porto, "but Larry ... was dealing with a museum and an educational institution. Their money comes from grants. So they can't just make a commitment to spend money on something, especially something as seemingly open-ended as this, using money that's already been budgeted for something else .... Larry failed to understand the inability of the Hall to act as quickly as he wanted them to." The Hall administrators, for their part, didn't seem to quite understand what Kuznets was up to, nor did they appreciate the depth of his dedication.

Even the flight deck instruments are illuminated realistically; colors mimic those on the real shuttle.

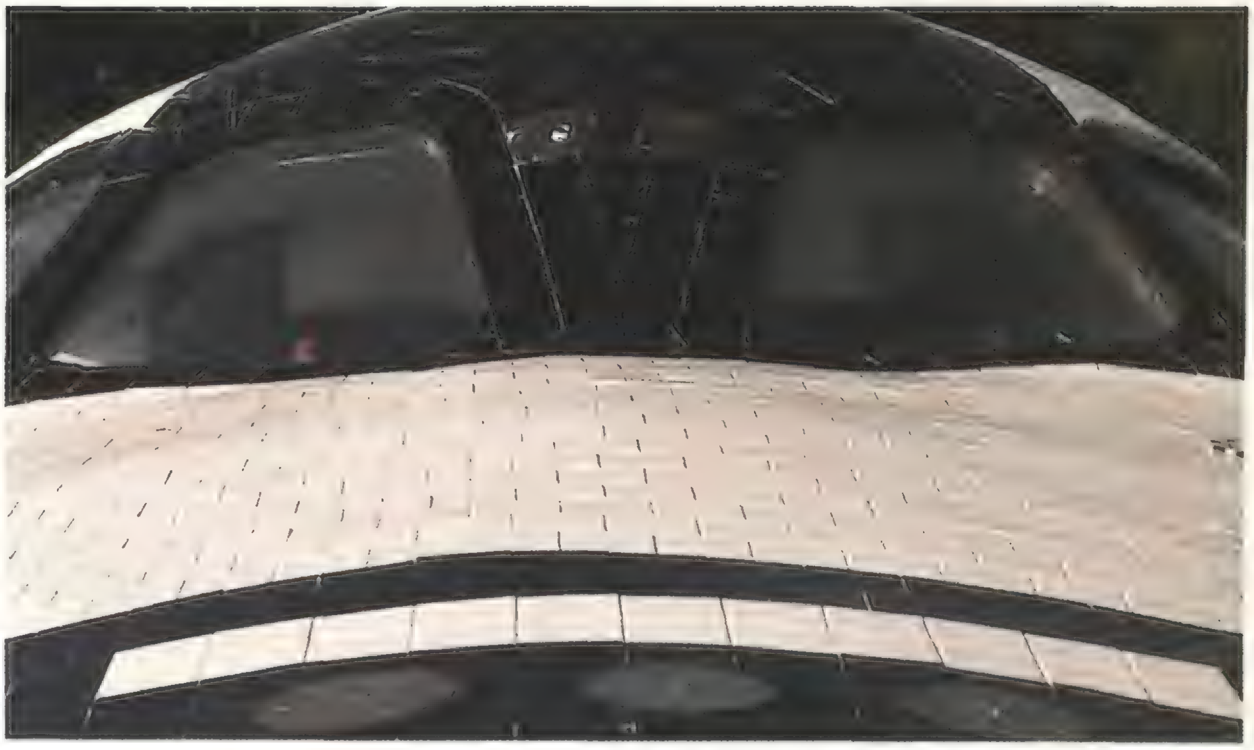
They almost certainly never imagined that Kuznets would move into the shuttle. Concerned about vandalism, and perhaps also to goad Hall naysayers, Kuznets lived and slept in the mockup for varying periods during the fall and early winter of 1986.

A year after the *Challenger* explosion, the students' project was virtually complete. The finished product was strikingly realistic, right down to the numbers on the astronauts' personal stowage bays and the hundreds of switches and dials on the forward flight deck. Astronauts, as well as friends and relatives of the *Challenger* crew, have come to visit and, according to Kuznets, "They're just very impressed."

But there was still no resolution in sight on the fate of the mockup. Ultimatums, pleas, letters, memoranda, and eviction notices flew back and forth throughout the spring of 1987. Rollie Otto, the Hall's new assistant director, arrived in the middle of the controversy and was given the unenviable task of attempting to sort through the issue and map out a policy. While sympathetic to

Kuznets' intentions, he worried about how the Hall could use—not to mention afford—the mockup. He was also justifiably concerned about how the structure could be modified to safely handle groups of visitors and comply with local fire and building codes without costly changes. The shuttle's builders had never had evacuation exits and fire-retardant measures in mind. Otto says he was "forced to take a hard-nosed administrator's role."

Finally, thanks largely to Porto's efforts, the two sides hammered out an agreement. Last summer the Hall's department of astronomy and physics developed a program for junior high school students to use the mockup. The replica was also opened for tours, which attracted as many as 150 people an hour, and the educational and public access programs continued through the fall. Volunteers performed some of the necessary work to make the structure safe, donations came in to help with funding, and the department of astronomy and physics chipped in as well.



Shuttle tiles—the genuine article—are interspersed among the kind that lines bathrooms.

Except for the view out the window, the aft-facing station on the flight deck duplicates an orbiter's.

Kuznets has moved on to other ventures. He is now president of Space Spinoffs, a Texas corporation. His experience with crew systems design at Johnson Space Center and the orbiter office at Kennedy Space Center, where he helped build the *Columbia,* is being put to work in his role as a consultant to companies that apply space technologies in innovative ways. One of his specialties is advising sportswear designers on dissipation of body heat.

The Lawrence Hall of Science seems happy with the way things have turned out. "It's immensely popular," says Otto. And there are intriguing possibilities for linking the structure with the museum buildings or even moving it inside. For the moment, though, the shuttle stands alone, its nose toward the Pacific, pointed outward and—if you use your imagination—upward.

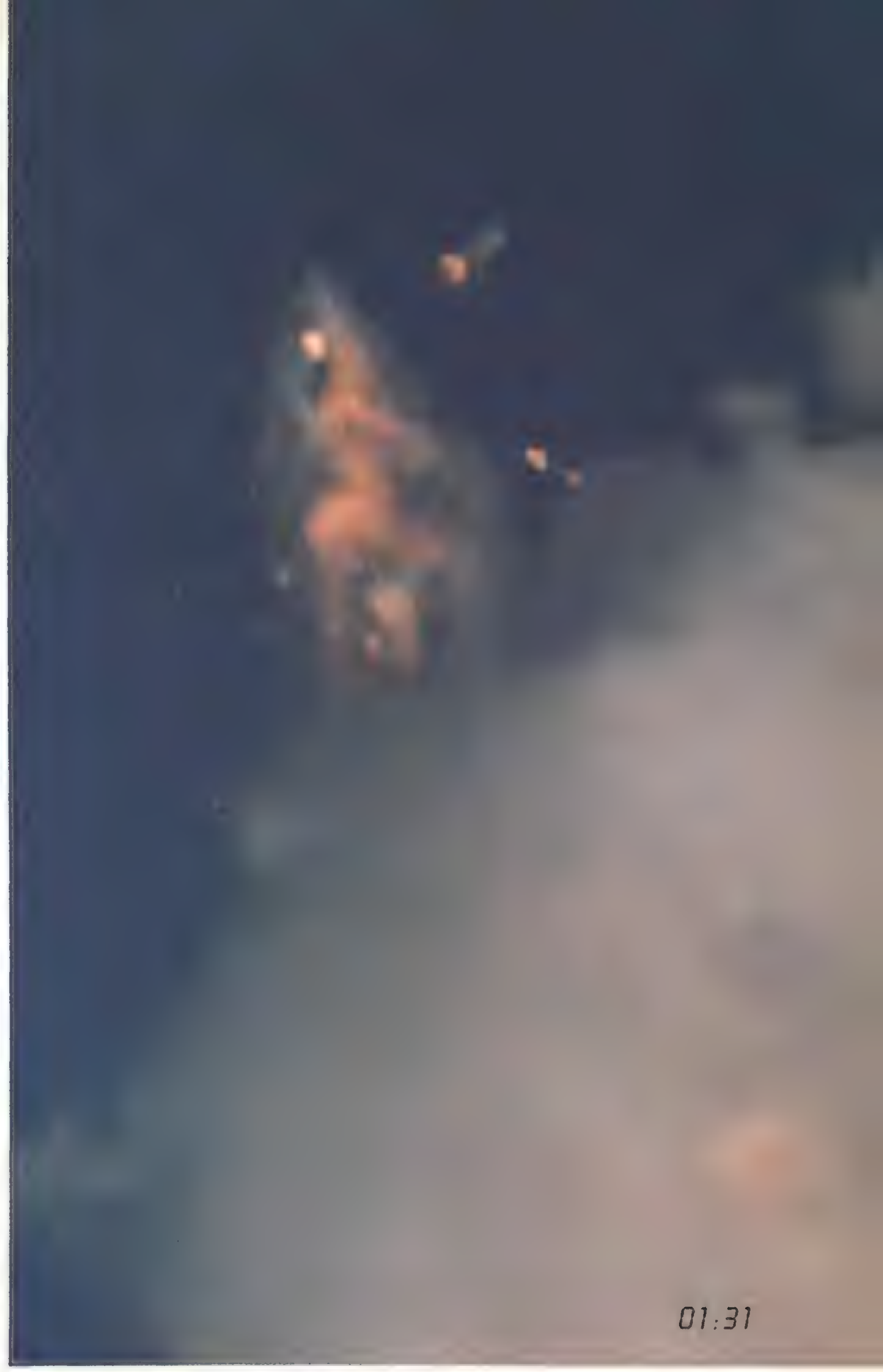
Pushing the Button

When a rocket launch goes awry, a range safety officer has to make some quick decisions.

by G. Harry Stine

NASA

Behind the launch of any big rocket lie a lot of hard work and a good sum of money. But rockets—complex and temperamental devices that they are—don't always work as their designers plan. When one of them runs wild, its controllers may have to destroy the errant vehicle before it hurts somebody. With the push of a button, a multimillion-dollar machine and its payload are turned into scrap.



The May 3, 1986 launch of a Delta rocket from Cape Canaveral began normally, and after 66 seconds the rocket jettisoned its second set of solid rocket boosters on schedule. Disaster struck at 71 seconds, when the main engine shut down prematurely. The Delta began tumbling out of control and was destroyed 91 seconds after launch.

Immediately following the destruction of the *Challenger* on January 28, 1986, range safety officials at Cape Canaveral radioed a command that blew up the shuttle's solid-fuel boosters, which had flown off on their own erratic course. On May 3, 1986, a Delta rocket carrying a $57.5 million satellite suffered an engine malfunction and had to be blown up. On March 26, 1987, an Atlas Centaur rocket launched from Cape Canaveral was destroyed when it veered from its flight path after a lightning strike.

The systems used in such situations were originally developed at the White Sands Proving Ground in south-central New Mexico. Established in 1945 to test emerging missile weaponry, including captured German V-2s, White Sands has been the site of over 36,000 rocket and missile launches. Not every one has been a success.

The missile range, located on a 100- by 40-mile strip of land in a lunar-like desert valley called the Tularosa Basin, lies 4,300 feet above sea level and is surrounded by mountains that rear up another 5,000 feet. The range includes Trinity Site, the location of the first atomic bomb explosion, as well as White Sands National Monument, noted for its startlingly white gypsum sand.

In 1945 White Sands contained little but sand, jackrabbits, rattlesnakes, lava flows, bare mountains, and a few ranchers eking out a living from some scrawny cows. The scenery has changed little over the years, but now nearly 9,000 people work at the range.

Originally it was assumed that the technicians would be able to keep the V-2s within the range boundaries. After all, the rocket had been designed to hit specific targets—like London.

Courtesy G. Harry Stine

Sometimes an RSO has an easy decision, as in the case of the July 16, 1959 launch of a Juno II.

To "aim" the V-2, the German rocket scientists had given it a thrust-terminating system. A signal sent by ground radio would turn valves that cut the engine's fuel and oxidizer, and the V-2 would end its flight as a four-ton artillery shell.

One V-2 launch that was cut off with this system took place on August 22, 1946. Four seconds after a normal takeoff, the 46-foot rocket turned on its side and began flying horizontally, an intimidating sight. One observer, who had been describing the launch on a field telephone, took off running while still holding the phone. When the slack in the phone cord ran out, he was yanked off his feet like a cartoon character. Another man tried to scramble through the barbed wire fence around the launch area, even though a gate stood open three feet away. Fortunately, the guidance engineer had the presence of mind to send the shutoff signal, and the V-2 made an abrupt return to earth.

But the incident that finally led to a range safety policy at White Sands occurred on May 29, 1947, with a V-2 again occupying center stage. The rocket, testing a classified guidance system for the Army's proposed Hermes ballistic missile, veered south instead of north because of a faulty gyroscope. Rather than plow a fully fueled rocket into the ground, the technician at the cutoff switch, believing the V-2 would safely fly beyond populated areas, decided to let the rocket burn all its fuel. It arced over El Paso, Texas, about 40 miles south of the range, and slammed into a cemetery near the Mexican border city of Juarez.

An Army contingent chased the rocket to Juarez, hoping that the impact had destroyed only the rocket and not any bystanders. They were lucky—no one was injured. Some entrepreneurs at the scene were even selling metal they claimed to be V-2 fragments.

Colonel Harold R. Turner, the White Sands commanding officer, called a meeting the next day and laid down the law: no rocket would be launched until its landing point could be predicted. If a rocket threatened to leave the range boundaries, its flight would be terminated. Turner put Major Herbert L. Karsch in charge of range safety.

Karsch, a strong-willed individual and former range safety officer for Army Ordnance, adopted features of the Army's artillery range safety practices. Before Juarez, a project officer for each launch was responsible for terminating the flight. Now a range safety officer would oversee operations. Once a rocket was in flight, the RSO's decisions could not be disputed, overruled, or appealed to higher authority, but if he made too many bad judgment calls, he could be replaced by his commanding officer, a drastic step taken only when the wrong decisions needlessly disrupted the launch schedule. From 1955 to 1957, I served as the U.S. Navy's RSO at White Sands.

In the clear desert air above White Sands, rockets could be tracked visually with a gadget called a skyscreen. A rectangular metal frame about 15 feet high and 5 feet wide, the skyscreen had two wires leading from a point in the center to the upper corners. The wires represented the safe limits of a rocket's flight path.

The skyscreen was located up to five miles from the launch site. During a flight a technician stood behind it, peering at the rocket through a peep sight. If the rocket crossed one of the wires on the screen, the technician used a range phone to call the flight safety transmitter shack and have it destroyed.

Rockets were also tracked by radar. In the early days at White Sands, the radar information was sent to a computer that drove a pen on a plotting board. The pen drew the course of the rocket on a map and plotted its altitude. Another computer determined where the rocket would land if the motor thrust were terminated at any given instant, and it plotted the site on a second map.

During a launch, the RSO would hold a switch as he danced from one plotting board to the other. If he thought the rocket was going to cross boundary lines drawn on the maps, he pushed the switch that sent the cutoff signal to a radio receiver in the rocket.

The receivers had to be protected from random radio signals, which could cause a rocket to destroy itself. In one safeguard system, the receivers would respond only to a classified cutoff signal made up of two or more audio tones. Another employed a fail-safe system: as long as a rocket received the signal it kept flying. If the signal was interrupted, the rocket self-destructed.

As insurance, technicians would also wrap a short length of explosive around the fuel lines, then cover it with tape to concentrate the explosive force. A radio command from the ground would trigger the explosive and cut the pipe. In addition, rockets with scientific payloads usually had explosives to separate the payload compartment and the tail fins from the rocket. The individual parts could then make softer landings than the whole rocket would.

The first V-2 launch I saw provided an unexpected show of fireworks. It was dawn on June 14, 1951, and I was watching the countdown about half a mile away, sitting on the hood of a pickup truck to keep warm. The rocket's engine took a second or so after ignition to build up thrust, enough hesitation to lift the entire 13-ton mass a fraction of an inch and cause it to jitter on its launcher. In that brief launch pad dance, the V-2 managed to short out the range safety ground connections that passed through a plug at its tail.

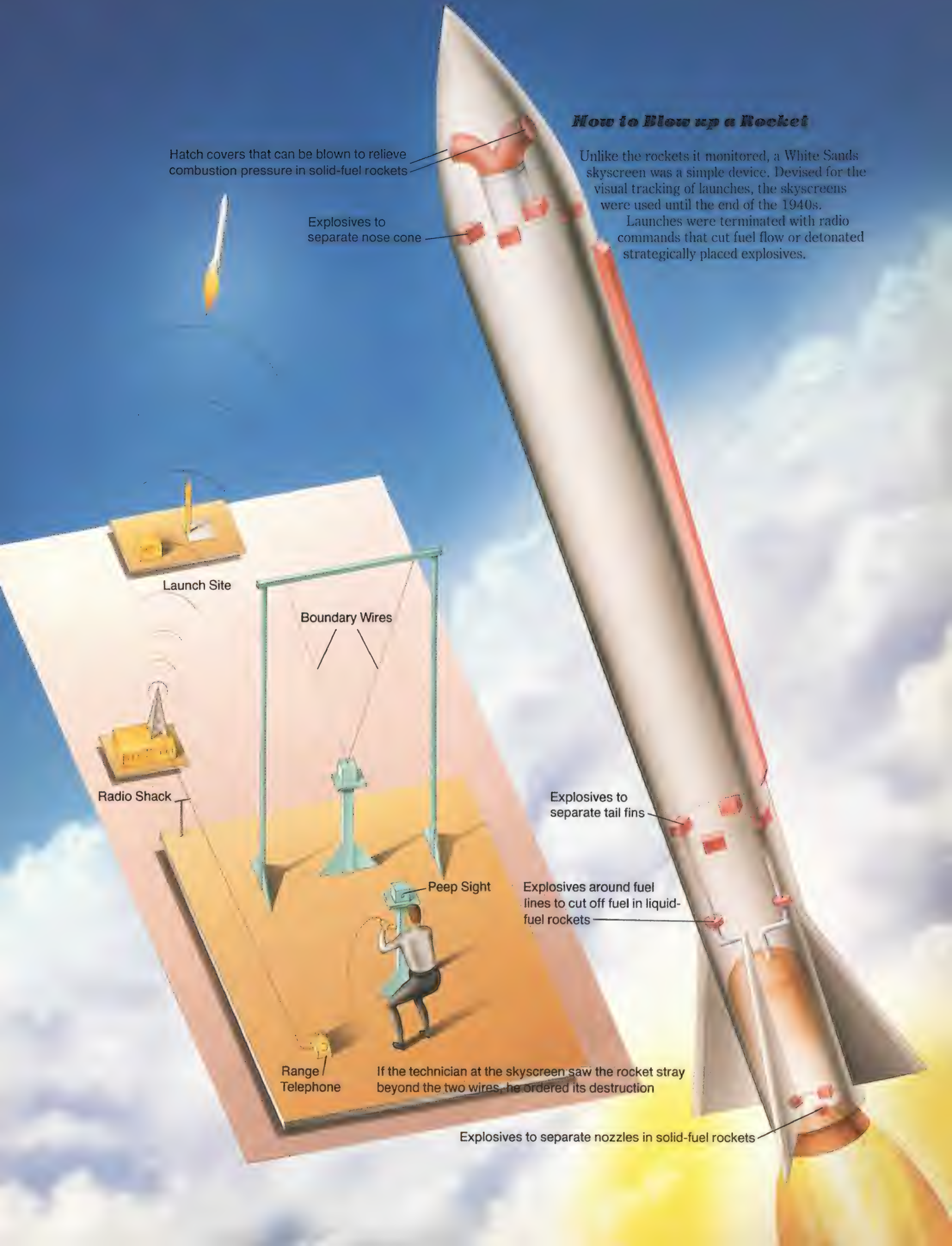
The first charge to ignite was the 40 pounds of explosives at

Dale Glasgow

How to Blow up a Rocket

Unlike the rockets it monitored, a White Sands skyscreen was a simple device. Devised for the visual tracking of launches, the skyscreens were used until the end of the 1940s.

Launches were terminated with radio commands that cut fuel flow or detonated strategically placed explosives.



Emergency Procedures

In the event that a space shuttle flight launched from Cape Canaveral had to be terminated, the range safety officer would have to send two separate commands—"arm" and "destruct"—from one of several 10-kilowatt transmitters. (These signals can originate only from the ground, not from the shuttle.) The arm signal is transmitted first and turns on a light in the shuttle's cockpit to warn the crew to separate the orbiter from the tank and boosters.

The commands, however, are not sent until after the following series of checks and double-checks, which takes microseconds.

(1) The RSO initiates the arm or destruct command.

(2) The signal is sent to a Central Computer.

(3) The CC compares notes with its back-up to confirm that an actual command from the RSO has been received.

(4) The CC queries the storage computer, which will generate the tone combinations to be sent to the shuttle.

(5) The storage computer sends the proper tone pairs to the CC.

(6) The CC rechecks that the RSO has really sent the command.

(7) The CC sends the tone pairs, on two separate telephone lines, to the selected transmitter.

(8) The CC erases its record of the tone pairs.

(9) The transmitter sends the tone pairs back to the CC.

(10) The CC checks once again that the arm or destruct command has been sent.

(11) The CC again retrieves the tone pairs from the storage computer and compares them to the pairs sent back by the transmitter.

(12) If they match, the CC sends the command to the transmitter.

(13) The transmitter sends the signal to the shuttle.

The casing of each solid rocket booster has a strip of high explosive running the entire length of the booster on the outboard side. When actuated by the Range Safety Command Destruct system, the charges will split open the steel casings, relieving the pressure necessary to sustain solid-fuel combustion. The external tank, too, has a shaped charge of explosive running along it. The explosives would split the tank open and allow the liquid hydrogen and oxygen to mix and burn.

It's very unlikely that the Cape's range safety destruct system could be infiltrated by saboteurs and used to destroy the shuttle or a rocket in flight. Any such hostile agent would have to know the proper tone pairs for the flight, then find a way to overpower the signal that saturates the onboard radio receivers.

—G. Harry Stine

the base of the nose. The alcohol tank went next, and it spilled its contents down into the liquid oxygen tank. The third explosion was the reaction of the alcohol-LOX mix. Then the 95 percent hydrogen peroxide for the turbopump blew. Finally, the explosive charge designed to separate the tail fins did its job. The people in the concrete blockhouse near the pad counted five separate explosions. I didn't, having been blown off the truck's hood and into a cactus.

On one occasion the destruct system worked to perfection when it shouldn't have. A Navy Viking—the replacement for the V-2—was bolted to the launch pad at two points on its tail for a run-of-the-mill static test of its engine. The bolts had been proof-tested to withstand one-third more thrust than the Viking's 20,000-pound-thrust motor could produce.

The motor started well, but nine seconds into the test it began to throb, which meant that the propellants were reaching it in surges. The thrust surged as well, rising and falling rapidly. Thirteen seconds after ignition, the Viking gave a mighty heave and broke loose from the pad.

Because the flight was completely unexpected, none of the radars was manned. No one was watching. RSO Nat Wagner was in the blockhouse just in case the motor had to be shut down during the static test. But the Viking was in the air, its ground connections severed, and without an antenna to receive a destruct command. It could fly as far as Santa Fe or Roswell, New Mexico.

Wagner grabbed the phone and ordered George Meredith at the main range safety radio transmitter to destroy the Viking. Meredith, knowing its receiving antenna hadn't been installed, cranked up the destruct transmitter and pushed the button anyway.

Four miles above the launch pad, the cutoff signal was picked up by the lead wires that would have been connected to

V-2 Number 55 never made it off the pad. On June 4, 1951, the rocket met a cataclysmic end when its range safety ground connections short-circuited.

NASM

NASM

Herbert L. Karsch (left, with General Electric engineer Leo D. "Pappy" White) was appointed head of White Sands' range safety in 1947, the first to occupy the position.

the Viking's antenna. Enough of a signal reached the receiver to shut off the fuel, and after a two-minute flight, the rocket crashed about four miles southeast of the launch pad. It still holds the altitude record for a static test.

Sometimes launches were complicated not by cranky rockets but by cranky scientists. One night the Navy was scheduled to fly an Aerobee sounding rocket, a little bird about 25 feet long and 15 inches wide. Stabilized only by its tail fins, the Aerobee was designed to fly like an arrow and could easily be blown off course by winds. To compensate, its 150-foot launch tower could be tilted a few degrees.

On the night of the launch there were strong jet stream winds at 37,000 feet and thunderstorms below. No matter how much we tilted the launch tower, the Aerobee, if launched, would have landed somewhere near Alamogordo, New Mexico, a town of about 15,000 people. I called the project scientist and suggested he postpone the launch.

Feeling a budgetary pinch that would only be aggravated by a postponement, he refused. "Doctor, it's your decision," I told him politely. "But if that Aerobee is launched, I'll have to push the destruct button the instant it clears the launch tower."

He launched. I pushed the button, went home, and got a good night's sleep.

The next morning I was called to the office of my boss, the Navy unit's executive officer. The scientist had lodged a complaint against me for destroying his rocket. My boss asked me for my side of the story. When I finished he said, "You did your job." That was the last I heard of it.

As rockets and missiles became more reliable and capable of flying longer distances, the White Sands policy of prohibiting them from leaving the range became obsolete. By the 1960s Athena rockets were being launched from Green River, Utah, and re-entering the atmosphere over White Sands, where tracking cameras and radars collected data on re-entry of ICBMs with various nose shapes and coatings.

Today range safety systems are almost magical. RSOs have high-speed computers, microwave tracking technology, and solid-state electronics at their fingertips. The space shuttle alone carries five destruct receivers: one on the external tank and two on each of the solid rocket boosters. The manned orbiter carries no destruct receiver or explosives. If any one of the five receivers picks up the proper signals—a classified pair of computer-created tones—it will activate the entire destruct system. A powerful and continuous ground transmission blocks the reception of any random signals (see "Emergency Procedures," previous page).

Range safety has come a long way since that V-2 made its surprise visit to Juarez. Someday, perhaps, rockets will be as reliable as jet engines, making such elaborate range safety procedures relics. Guidance systems, too, may be able to maneuver a rocket with pinpoint accuracy. Until that day, however, RSOs will have the task of monitoring rockets and destroying the failures, no matter that others have spent and labored mightily to get them into the air.

Paper Doll

The crew of Paper Doll, *the eponymous B-17 of Jim Shepard's novel, are not battle-hardened veterans. Poorly trained and inexperienced, they are little more than children, fighting a deadly war in the skies above Europe. Bobby Bryant,* Paper Doll'*s flight engineer, is so unsure of his abilities that he has learned to leave mechanical questions to the crew chief, Tuliese. Bryant's closest friend, ball turret gunner Gordon Snowberry, 17, lied about his age to join the Army Air Corps. "Guys in the 351st named one of their planes* The Baby Train,*" says Lewis Peeters,* Paper Doll'*s razor-tongued tail gunner. "I know what they were getting at, boy."*

Tuliese was on one knee, leaning precariously beneath the ball turret, tools fanned out beside him in the shade of the fuselage. On the back of his fatigues he had stenciled *May Your Ass Never End Up on a Drumhead.* The clip and case ejector chutes for the turret were disassembled and curled neatly inside one another on the grass.

"It's the hydraulic line," Tuliese said, instead of hello. "With this turret, it's always the hydraulic line." He had hung rags of various sizes from the barrels of the machine guns. Bryant thought of the Italian clotheslines in North Providence.

Tuliese knew what he was doing, and their working relationship was such that Bryant was asked only to contribute his presence much of the time, to testify to the importance of what was going on. Snowberry, more in the dark than he was, and with more at stake in this case, this being his turret, poked closely at the nozzle assembly and offered odd and tangential suggestions. Tuliese accepted them the way he might have a child's, and Bryant recalled a *Saturday Evening Post* cover, a tow-headed boy offering incongruous tools to help with Dad's Hudson.

"I heard this horrible story from Billy Mitts," Snowberry said. "Belly gunner in the 100th. You hear it?"

Bryant shook his head. There were a lot of ball turret stories going around.

"This guy was in a Liberator that went down short of the field in Long Stratton—did one of those numbers through a thicket, ended up in big pieces all over some guy's estate. The belly gunner came out of it without a scratch."

Bryant nodded. "That's a great story," he said.

"Listen, listen," Snowberry said. "This guy, he gets out, it turns out, he's the only one there. He's calling and calling, and crawls around the pieces, no bodies, no nothing. Turns out everybody bailed out. They gave the order and his interphone must've been shot out. He'd come all the way in and crashed alone."

Tuliese snorted to indicate that the idea appealed to him. He was feeding a new length of flexible hydraulic line onto an accepting nozzle.

"I can't get over that," Snowberry said. "It gives me the jeebies just thinking about it."

"Listen," Bryant said. "The word ever comes to jump, I'll make sure you're in the know. My mother's honor."

"Just leave a note for him, Sarge," Tuliese said. "Plane goes down, it's every man for himself."

"Come on, Tuliese," Bryant said. "He doesn't think it's funny."

Tuliese looked at him without sympathy. Sweat stains under his arms connected at his sternum. Word was he hadn't changed his undershirt since landfall in England.

"Why not?" he said. "He thinks everything else is." . . .

"Hey, come on," Snowberry said. "Imagine coming in alone like that?"

"You think that's bad," Tuliese said. "You oughta ask Peeters about that poor son of a bitch in *Cheyenne Lady*. Ott. Dick Ott."

"Is this the guy in the tail?" Bryant asked. He hated when the conversations took this you-think-that's-bad direction.

"Ott? The wacko guy?" Snowberry asked.

Hydraulic fluid squirted from the line connection across Tuliese's arms. "This guy, don't ask me why he isn't off making pencils right now. He was on a ship called *Flying Bison,* they're not even over the Channel yet, barely at altitude, and something goes wrong with the oxygen to the waist gunner. He passes out. Pilot goes looking for air and drops them eight thousand feet but panics and pulls out too fast, and the control cables go, and then the whole starboard wing."

Many of Tuliese's stories carried a cautionary component involving reckless pilots damaging well-maintained aircraft, with fatal and grotesque results.

"The wing root pulls the bomb bay doors off, they shear back through the fuselage, and tear off the tail. Ott's in it alone, ass over teakettle at twenty-four thousand feet. It's spinning like one of those seed pods gone nuts. The windows won't give and the centrifugal force is pinning him against the seat. He finally kicks his way around to face the opening and tries to squeeze by the seat assembly. And gets his shoulders caught on the armor plate."

They sat rapt, listening to a story they'd heard before. The only sounds were those of Tuliese's tools.

"He must've been at a thousand feet he finally got clear, got his chute open, hit with a helluva crack, broke both legs. Rest of the plane came down in the same field, like a brick. Nobody else made it."

"Lewis told me that story," Bryant murmured.

"This guy is still flying." Tuliese said it as though it had a terminal eloquence about the mental state of flyboys. "He screams at night and sometimes, a guy told me, they find him moving his bed so it's at a right angle to the other beds. Me, I'd think I was Napoleon at that point." . . .

Tuliese repacked his tools and left without mentioning whether or not the turret was now fully operational. After he'd left, they sat with their backs to *Paper Doll*'s tail wheel, the aileron over their heads an enormous low ceiling, like a boy's hideout . . . .

Snowberry clunked his flying boots together at the toes. They were oversized enough to be his father's. "God, I wanted to be a fighter pilot," he said. "I thought they were the end. Girls die for fighter pilots. They only get wounded for us."

Illustrations by John L. Heinly

"I was a Lindy nut," Bryant said. "Were you a Lindbergh nut? He came and gave a speech in Providence and they sold little hats. I think it was about staying out of the war, but what did we care? It was Lindy."

"Oh, boy," Snowberry said. "I must've made two thousand *Spirit of St. Louis's* from those wooden Popsicle sticks. House was knee deep in *Spirit of St. Louis's*."

"I used to play toy soldiers," Bryant said. "The cardboard kind, with the wood bases. I had a little lead *Spirit of St. Louis,* used to fly over, strafe the soldiers. I used to have the guys go, 'Look out! It's Lindy! Aaah!' No one stood up to the airplanes. Everyone did a lot of running and dying."

"Like now," Snowberry said. "The Krauts: 'Bryant and Snowberry! Aaah!' "

They laughed. Bryant had a vision of flak crews in Germany chafing at the insult, crossing hairs over the belly of *Paper Doll,* and sobered.

* * *

When they pulled back the curtain on the mission board the next morning, the red yarn ran to Paris, and an enlargement of the target area was headed *Le Bourget.* Snowberry and Bryant looked at each other immediately and understood. Le Bourget was where Lindbergh had landed after the solo Atlantic flight. Le Bourget had always been for the two of them part of the legend. It was as if they were going to bomb *The Spirit of St. Louis.*

They were going after the depots where reserve aircraft and crews were believed to be. Lewis didn't like it. "Fighters," he said in a low voice during the briefing. "Why are we going after fighters?" Bean sat beside him and registered nothing.

They would have fighter escort the whole trip, they were assured, P-47s all the way there and back. Enough Little Friends for a party.

Lewis murmured about fighter suppression as they filed out: Why were they using B-17s for fighter suppression? There *was* something strange about it: the operations map showed clear weather over most of western Europe, and there were plenty of more important targets spread in an arc across the map. Bombing airfields was not the most efficient use of heavy bombers. The crews didn't complain—the airfields were not as heavily defended, usually, as strategic targets.

"Just do your job, General," Snowberry said. "Nobody said it had to make sense. Let someone else run the war."

"Maybe they want to give us a rest," Bryant suggested.

"I think you hit it," Lewis said. "I'm worried about why."

In the jeep to the hardstand he added, "I don't think it's for what we did. I think it's for what we're gonna do."

In the dark and cold plane Bryant swung experimentally on the sling seat in the turret and eyed the turret canopy critically. He wished he'd overseen the day's cleaning of the Plexiglas; now it was too dark. Gabriel asked over the interphone with some sarcasm if he'd like to be a part of this morning's pre-flight systems check.

They waited two hours for the ceiling to lift so they might have a safer assembly and finally went off just at dawn, a vivid orange

band beneath a purple one behind the darkened and backlit horizon. The Plexiglas surfaces of the ships ahead of them in taxi position glowed with the colors.

They hooked up with a reassuringly large flight of olive green razorback Thunderbolts—as far as Bryant could tell, there were more escorts than bombers—and the gunners joyfully called in each P-47 flight as it slipped into place until they felt they were approaching Paris cocooned in Air Support.

The Thunderbolts positioned themselves above the formations and wove lazy-S patterns to maintain contact with the slower Fortresses. No one in *Paper Doll* saw enemy fighters until the formation made its wide turn out of the echeloned vees into the column of groups that formed the long train for the bombing run. The higher squadron swung in alongside *Paper Doll* and in the process, in a rare instance in which the purest chance crystallized like a well-laid plan, they trapped inside their newly formed defensive box a hapless lone Messerschmitt Me-110 that had magically appeared at three o'clock low just outside Piacenti's window. The unhappy Messerschmitt flew level between them for a long moment. The pilot was gazing over at Bryant like someone about to get it in an old Mack Sennett short. His fuselage was dark gray with a white nose, with what looked like a little green fanged worm on the cowling. And then all hell broke loose, Bryant and Piacenti and Snowberry together hosing the fighter with tracers as the other planes around them opened up as well, the tracer lines converging from all directions like a starburst in reverse. The 110 seemed to stop and rear in mid-air, and pieces flew off like bits of confetti. It turned a baby blue underside to *Paper Doll* and then three tracer streams converged dazzlingly on the same point, like a mirror catching sunlight, and it disintegrated and flew backward out of the formation in a rain of shapes.

Smoke from the guns of the formation all around him trailed back from the bombers in satisfying streams.

"God, that was great," Snowberry said over the interphone.

"That's the best, that's amazing, to get them like that," Piacenti said. Bryant was trembling and overheated. He fired his guns out into space, overwhelmed by how intense the gratification had been, the physical pleasure detached from emotion, from any thought of the absurdly forlorn Mack Sennett face in the canopy before they had let fly. He watched the bombs rain down over Le Bourget, on Lindy's head, and felt as though a part of him were killed off, and had no regrets. They burst yellow and white in the rapid streams of the bombing pattern and the smoke bloomed and spread like stirred-up muck in pond water. "Bye, bye, Bourget," Snowberry said over the interphone, for Bryant's benefit. "Hope the *St. Louis* was off at a dispersal site."

Lewis reported a perfect bombing pattern, and added as an item of interest that somebody's bombs had torn the wings off a fighter attempting to climb beneath them. On the flight home they had maintained perfect formation, the spread of graceful Fortresses ahead and above him beautiful against the sky, and the Thunderbolts had swooped and looped around them after they had cleared the coast, celebrating with their own near-animal grace the ease and success of the day.

There was a minor celebration after debriefing, with Cokes and watery Scotch that Cooper and Gabriel had stashed away. There had been no announcement but already there were signs of another mission the next day, which was supposed to mean no drinking. After their triumph they interpreted that as a little drinking, confined to the afternoon. Gabriel announced to the assembled crew that Snowberry, Bryant, and Piacenti had each been awarded a third of a kill for the Messerschmitt and proposed a toast now that *Paper Doll* had been officially baptized. Now that the Luftwaffe has felt the sting of our anger, he added wryly. They drank the Scotch and Coke and poured water over each other's heads. It was only late afternoon and the minute amount of Scotch allotted Bryant made him woozy. It tasted like the metal cup.

"I've got an announcement," Gabriel said. "Thanks to the selfless bravery of Tech Sergeant Gordon L. Snowberry, Jr.—"

"L?" Snowberry said. He was rapidly finishing a loose pile of sketches.

"—L. Snowberry, Jr., we were able to obtain gun camera footage of *Paper Doll*'s historic kill today."

Bean looked at Bryant. Gun cameras were altogether glamorous gizmos reserved exclusively for fighter pilots. The notion of *Paper Doll*'s gunners employing gun cameras was akin to the idea of their jousting over aerodromes with the Red Baron or Max Immelmann.

"Gather round. Somebody hit the lights."

It was a sunny midafternoon and they were sitting around crates outside the day room. The crew gathered closer and Snowberry stood before them with his pile of sketches at chest level. On the first was a number 5 ringed with a geometric pattern like a cue number on a film leader. The men laughed.

Snowberry began to flip the pages, rapidly dropping them to his feet, and as the other numbers appeared the crew chanted the countdown, as they did before base movies: 4, 3, 2, 1. The first sketch appeared, a few lines suggesting a B-17 with an oversized tail. The men cheered. The next showed the formation. The next showed a ball turret. The next showed the same ball turret, from a slightly different angle. The men hooted and complained.

The drawings began to change more quickly as Snowberry developed dexterity with the flipping, and the B-17 began to bank—though there was some argument in

the audience as to whether it was in fact banking or whether a wing was falling off—and the Messerschmitt appeared, to a huge cheer. A close-up of the canopy revealed a fierce-looking Nazi with an eye patch, a dueling scar, and jagged teeth, and the crew hissed and booed. Across his fuselage were a string of tiny bull's-eyes that an arrow and tag helpfully identified as "37 Downed Brit Bombers." In the next drawing the Messerschmitt was approaching the viewer head on, guns blazing in sunlight-like rays. In the next, *Paper Doll* was viewed from the beam, with stick figures in the dorsal and waist windows firing.

"That's Bryant. I could tell by the shape of the head," Willis Eddy called.

"And Piacenti 'cause his hands aren't on the guns," Lambert Ball said.

More sketches of the firing, the tracer streams double-dotted lines. Bryant's and Piacenti's guns were missing high. Snowberry's belly turret, now visible, was firing right into the cockpit.

A big explosion, a swastikaed tail flying outward with lines of force.

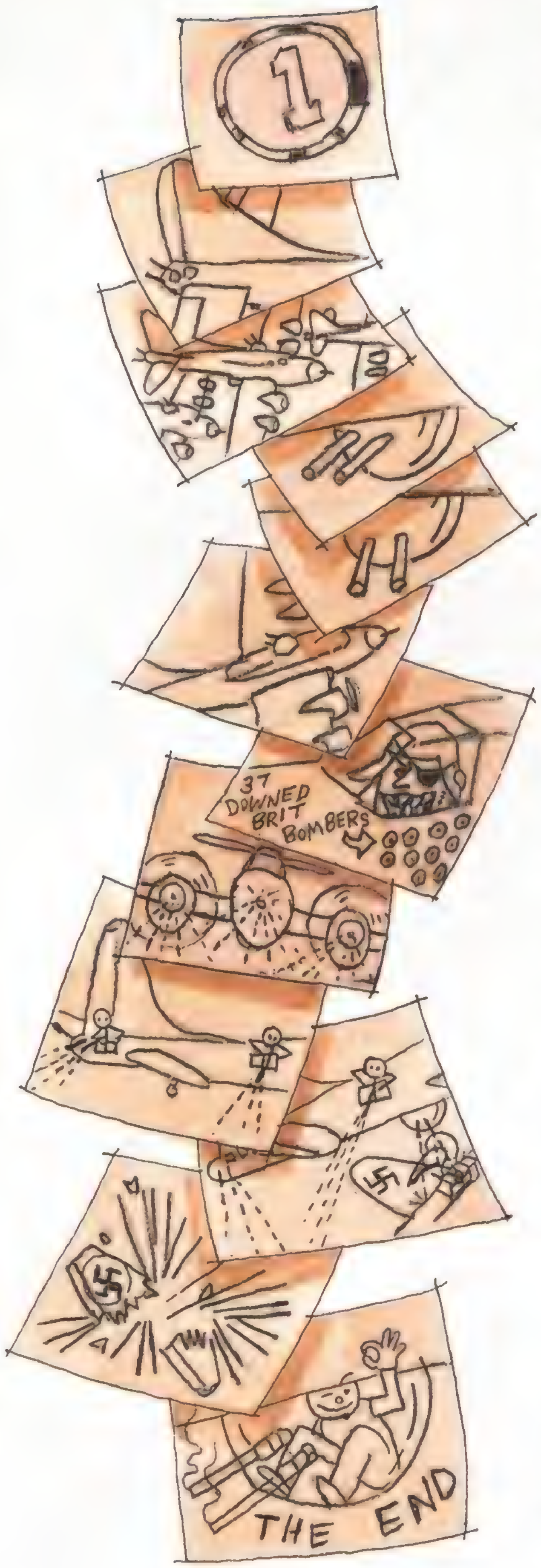
A final drawing, over which was superimposed THE END: a cartoon Snowberry curled inside the ball, winking, holding up an okay sign.

The men booed and threw gear. It did seem to Bryant as though morale had picked up . . . .

Lewis stood and suggested a game of Gordon Pong, and over Snowberry's protestations the idea was enthusiastically endorsed by the rest of the crew. Four crates were stacked two on two as a net and Snowberry was caught and dragged to one side. After some rules debate, it was decided that he would not be allowed to bounce once on the receiving team's side.

He kicked and squirmed too much—it was hard to maintain a good throwing grip—so they sat on him and tied his arms and feet. The officers agreed to play, and it was Bryant, Piacenti, Lewis, and Ball against Gabriel, Cooper, Hirsch, and Eddy. The gunners against the ninety-day wonders, as Lewis put it. Bean refused to play.

On the first toss Snowberry shrieked, so it was decided to gag him as well. After a few more tosses the best tactics revealed themselves to be: on the receiving end, spread out and close to the body as it flew over the crates; on the throwing end, try to produce a spin which would overload one end of the opposite line and defeat attempts at a good solid grasp. After one throw from the officers that just cleared the crates—Lewis called net ball but was argued out of it—Bryant commented to the group on the sheer terror in Gordon's eyes, and recommended a blindfold, both as a mercy



measure and further elimination of distractions. It was agreed to, and Bean gave up a sock to that purpose when no one was able to produce a handkerchief.

The officers were ahead 3 to 0—they scored when any part of Snowberry touched the ground as the gunners caught him, tallying on two real rib-thumpers and a cheapie can of corn when a limp foot touched—when Lewis abruptly announced Refreshment Break. He poured a bit of Scotch from an abandoned cup into his Coke bottle and took a slug . . . . He and Bryant sat beside Bean while Piacenti and Ball laboriously began to untie Snowberry, who was again showing signs of life. Lewis offered his Coke and Bean shrugged it off.

"I hate to see a grown man dry," Lewis said.

Snowberry was helping them now with his feet. "You guys," he said with diffused menace. "You guys."

"What a stand-up bunch of personnel, huh, Bean?" Lewis said. "Even when the going gets tough, there's still time for horseplay."

The victorious officers had left. Snowberry pouted where he lay, rubbing his hip. There were tears in Bean's eyes.

I don't know what I'm *doing* here," he said. "What am I *doing* here?"

Bryant patted his shoulder. Lewis said, "You don't have to figure it out. Like today. All you have to do is turn on the Brownings and let them figure it out."

Piacenti had started the jeep and was waving them over. Gabriel wanted another photo. Piacenti leaned on the horn, and revved the engine.

"I guess it's my buddy," Bean said. "I guess I haven't gotten over him."

"He's dead and you're not," Lewis said.

"I feel bad," Bean said.

"Feel good," Lewis said.

"He told me if anything happened to tell his girlfriend the real story," Bean said. "I think about that."

"I think about home, takeoff, assembly, their fighters, our escort," Lewis said. "Flak."

They helped Bean to his feet, and climbed aboard the jeep. At the plane Gabriel arranged them as he had before. Snowberry said, "Why don't you make little white marks on the fuselage over our heads so you can see how much we've grown?" For the photographer, though, he joined with everyone else in pointing to the newly painted iron cross on the nose, and holding up one finger.

NASA's Spin-Off

Judy King-Rieniets/Stansbury, Ronsaville, Wood Inc.

After three days of tests, NASA confirmed what the operator of a carnival ride told me 38 years ago: I'm a "high susceptible" when it comes to motion sickness. Of course the carny used more down-to-earth terminology, something like "Can't hack it, huh, kid?" But at age 11, I had only been trying to master a gut-wrenching ride called the Spitfire. I had yet to be introduced to NASA's version: the MCRD, for Man-Carrying Rotation Device, a small, spinning, windowless room used to induce motion sickness.

The MCRD exists because half of the astronauts on Apollo, Skylab, and shuttle missions have been afflicted with what NASA calls space adaptation syndrome, also known as SAS and space motion sickness. The causes of space-based and Earth-based motion sickness differ, but physiological responses are similar. Typical symptoms of the Earthly version are pallor, cold sweats, nausea, and vomiting, in that order. Those of space motion sickness are not so predictable—for example, nausea and vomiting come and go inexplicably. Severity ranges from "this isn't too bad" to "if only I could die."

Patricia Cowings is a NASA psychophysiologist who's been studying motion sickness since 1973. She makes people sick for the greater good of future astronauts, whose time on the job is worth far more than the average worker's. Even lethargy and lack of initiative are costly symptoms when an astronaut needs two or three days to overcome SAS. The MCRD is an efficient Earthbound partner in crime in producing motion sickness. "If a rock had an inner ear," Cowings says, "it would make a rock sick."

Certain rocks, coupled with gravity, balance us on Earth. Tiny calcium pebbles in the inner ear called otoconia respond to motion and report to the brain. Combined with visual clues, these reports tell us if we're standing, sitting, lying down, or in transit. But that's in a one-G environment. In the weightlessness of spaceflight, when humans are in a perpetual free-fall, the otoconia wander within their chamber and cannot provide accurate orientation cues.

While visual stimuli and fluid shifts in the body may contribute to space motion sickness, Cowings says the primary cause is the wandering otoconia. Since 1972 only six subjects who have ridden the MCRD or a rotating chair have suffered no ill effects. Five of them had nonfunctioning otoconia, a condition found in one of every 5,000 people.

Bill Toscano, Cowings' husband, collaborator, and one of her first research subjects, had no adverse reactions during his two-hour MCRD ride. "We thought the thing was broken," Cowings says. "Then I got in and was sick within 15 minutes, just like you're supposed to be." Toscano subsequently learned that he had bum otoconia.

The sixth unflappable subject, 42-year-old pilot Terry Brennan, has not yet been tested for otoconia function. Brennan does aerobatics in a Beechcraft T-34 Mentor and is well acquainted with vertigo, but what he experienced in the MCRD was somehow different. "I felt dizzy as I tilted my head in various directions—the symptoms were there, but they just didn't have a tremendously upsetting effect," he says. "And I never had any of the symptoms they ask you about every five minutes."

Brennan's exchanges with the control room bordered on monotonous. Temperature change? "No." Headache? "No." Drowsiness? "No." Sweating? "No." Salivation? "No." Stomach sensitivity? "No." Would you like to continue? "Why not?" He did, lasting for an hour and progressing from six revolutions per minute to more than 20.

Last May, the Human Factors Laboratory at NASA's Ames Research Center in Mountain View, California, gave volunteers rides in the MCRD to study their response to motion sickness. My group was an even mix of high susceptibles and low susceptibles.

The MCRD's black interior disoriented me right off the bat. I was wired to an array of monitoring devices that report on physiological responses, such as pulse, respiration, perspiration, and blood pressure. Instruments used for the first time on my group measured strength of heartbeat and efficiency of respiration. A camera permitted the researchers to keep an eye on us. Just before closing the door, an aide hung a plastic bag around my neck. I hoped the researchers were sincere when they claimed they didn't really want to make me sick, only bring me to the threshold. Cowings claims that only 10 out of several hundred MCRD riders have gone over the edge.

The MCRD spins like a top, but because of the lack of visual cues the passenger senses motion only during acceleration and deceleration. When the box is up to speed, all is well as long as you don't move. However, even the slightest tip of the head brings on the sensation of falling head over heels. When I started following commands to move my head left, right, up, and down, I was suddenly clammy, then sweating profusely, then slightly dizzy, then nauseated. Temperature change? "Yes." Dizziness? "Yes." Sweating? "Yes." Salivation? "Yes." Stomach sensitivity? "Yes." Do you want to continue? "I think that's about it." But I lasted a full 15 minutes on my second ride—the body begins to adapt once it knows what's coming. So far, astronauts who've suffered from SAS only did so once.

Cowings is convinced that something called autogenic feedback training can teach people how to fend off space motion sickness. AFT combines biofeedback, self-hypnosis, and behavioral techniques to avoid fixating on symptoms. "It will work for any motion sickness condition—at least on Earth—given enough time," she says. "If your heart rate accelerates, we teach you how to slow it. If you breathe raggedly, we show you how to breathe evenly. People who learned to maintain resting physiological levels were able to ride longer. I've never come across anyone who could not learn to control their symptoms to some degree."

The Human Factors lab has given six hours of AFT to more than 200 subjects, including payload specialists training for shuttle flights. Cowings says 60 percent gained complete control over their responses, and up to 25 percent significantly improved. "If you can't avoid or modify your environment, you modify your response. It's a capacity we all have. Animals can control autonomic and even glandular responses, so it's not surprising that people can too—a man is at least as smart as a mouse."

But that success rate is Earth-based. So far Cowings has monitored only four subjects on shuttle flights, two using drugs to ward off motion sickness and two using AFT. The people on drugs got sicker than the people who relied on AFT. More data will be slow in coming. "If I can experiment with one mission a year I'll feel very lucky," she says. Meanwhile, she relies on volunteers to help refine her AFT techniques.

After my rides I tried biofeedback training and now have nearly total control over my persistent headaches. That increases my confidence that someday I'll make a space flight. I might even find another carnival and try the Spitfire again.

—Bob McCafferty


WRIGHT FLYER (1903)


SOPWITH CAMEL (1916)


SPITFIRE (1936)


MESSERSCHMITT Bf. 109E (1939)


DOUGLAS DC-3 (1935)

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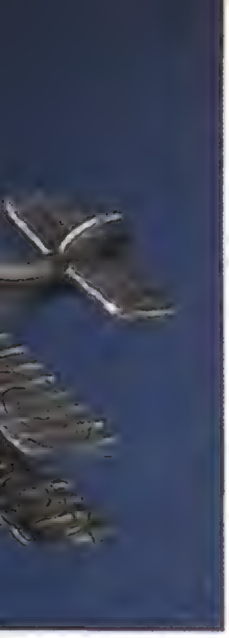
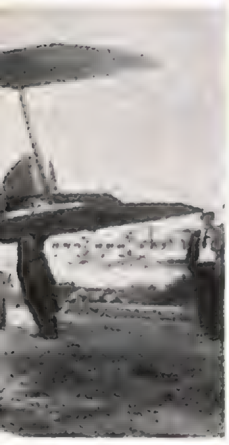
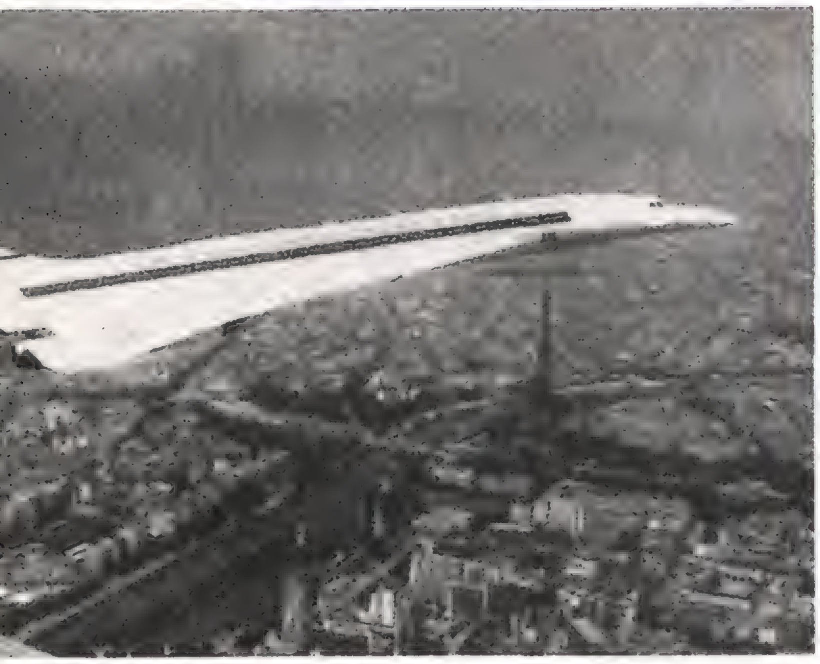


BOEING B-17 FLYING FORTRESS (1943)

GRUMMAN F-14 TOMCAT (1972)





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Reviews & Previews

Universe *edited by Byron Preiss. Spectra/Bantam, 1987. 335 pp., color photos and illustrations, $24.95 (hardbound).*

Cycles of Fire *by William K. Hartmann and Ron Miller. Workman Publishing, 1987. 189 pp., color illustrations, $27.50 (hardbound), $14.95 (paperback).*

Several years ago, while lingering in a small Irish village, I informed my landlord that I was a writer—"about astronomy," I said. For days thereafter, I was invariably introduced as "Mr. Cornell, the science fiction writer." With a typical Celtic mixture of irony and insight, my host had recognized the long-standing, if seldom noted, link between the science of astronomy and the art of speculative fiction.

In unguarded moments, some astrophysicists admit to being turned on to science by youthful exposure to tales of space travel and alien invasions. At the same time, almost all science fiction authors readily acknowledge their debt to the bizarre cosmic phenomena, both real and theoretical, offered up by astronomical research.

Byron Preiss, editor of *Universe,* celebrates both kinds of cosmic vision while attempting to demonstrate their compatibility. Essays by scientists on particular aspects of astronomy—galaxies, quasars, black holes—are coupled with speculative short stories based on some element of the science. Both are illustrated, the essays with space- and ground-based photographs, the fiction with futuristic art. The result is slightly weird, sometimes wacky, and totally wonderful.

Ron Miller

Symbiotic stars are among the space oddities presented in Cycles of Fire.

That the talent is top-rate certainly helps. The scientist-authors include many well-known popularizers, such as Isaac Asimov, Eric Chaisson, and Wallace Tucker, as well as others better known for research than writing, such as Hyron Spinrad and Alan Sandage.

Given the usual time lags in book publishing and the rush of recent discoveries, the book is extraordinarily up to date, with a mention of Supernova 1987A and a reference to the expected observation of quasars at extreme redshifts (the discovery of the latest "most distant" quasar was announced just last December). Credit for this timeliness and the smooth explanations of complex concepts goes to scientific editor Andrew Fraknoi, whose essay "The Universe" offers an excellent introduction to the volume.

Similarly, the speculative fiction, all new pieces commissioned for this book, is superb. This genre often suffers from unevenness, but with old masters like Gregory Benford, David Brin, Rudy Rucker, and Robert Silverberg as contributors, there is hardly a clunker in the lot. Several stories, most notably those by Connie Willis and Frederik Pohl, remind us that the best speculative writing shares a quality of all good fiction: concern for human values and hopes, triumphs and tragedies.

The only possible disappointment is the artwork. While the illustrations may be scientifically approved, they are a bit too conservative for my taste. As one brought up on pulp magazines, I miss the death-ray guns, voluptuous space maidens, muscle-bound warriors, and slimy eight-armed aliens (see "The Three Bs," p. 24).

Fortunately, any need for the fantastic in art can be more than satisfied by *Cycles of Fire,* another semi-speculative voyage through the universe in words and pictures. William K. Hartmann, a planetary scientist and illustrator, and Ron Miller, a former staff artist with the National Air and Space Museum's Albert Einstein Planetarium, helped by artists Pamela Lee and Tom Miller, have created a plethora of strange worlds in this, their third volume in a trilogy of unusual astronomical imagery.

In the previous volumes they limned our solar system. Here they move into deep space and let their imaginations run riot—or nearly so. Actually, the environments they depict—planets orbiting multiple-star systems, colliding galaxies, black holes—are based on sound science and accepted theory, with just a dash of what Hartmann calls "intuition" thrown in.

The variety of stars within our own galaxy provides endless opportunities for

variations on the theme of shattered landscapes bathed in multi-hued light or swathed in eerie shadows. And beyond the galaxy, where speculation dominates, Hartmann and Miller's scope expands to include the mysteries of creation, cosmology, and the possible emergence of otherworldly life-forms.

Among a score of stunning images, my favorite is a close-up of a great galactic pinwheel viewed from a hypothetical planet circling a sun in a nearby satellite galaxy. "Imagine," writes Hartmann, "the mythology and astronomy that might develop among sentient creatures on a planet with a glowing, celestial spiral illuminating its nights." Imagine, indeed! For now, at least, the regions of the cosmos envisioned here lie beyond our reach, but art like this can bridge light-years and send us soaring.

Hartmann and Miller are working in a time-honored tradition, one pioneered by the late Chesley Bonestell. His spacescapes inspired hundreds of current stargazers. Who knows how many future astronomical careers may be sparked by these views?

—James Cornell, publications manager of the Harvard-Smithsonian Center for Astrophysics, has written and edited several books on astronomy.

Warner Bros. Inc.

Empire of the Sun *directed by Steven Spielberg. Warner Bros., 1987.*

Steven Spielberg's *Empire of the Sun,* a film based on J.G. Ballard's semi-autobiographical novel, tells the story of Jim (played by Christian Bale), the 11-year-old son of British parents living in Shanghai on the eve of Pearl Harbor. Jim is fascinated by war, especially by warplanes, and experiences war-threatened China as a kaleidoscope of exotic sounds and images that captures his imagination.

But then war breaks out, Japan takes Shanghai, and British subjects are interned in a Japanese prison camp in the country for the duration of the hostilities. Torn from his privileged life, Jim must learn to survive in a world turned upside down.

Jim's loyalties go to whichever side has the best airplanes. At first he reveres the Japanese Zero, but as the war progresses he shifts his allegiance to the U.S. P-51 Mustang, which he calls "the Cadillac of the skies." Audiences can appreciate why during a dazzling sequence in which sleek P-51s attack the Japanese airfield located next to the prison camp.

The P-51 attack is just one example of Spielberg's technical brilliance. As a whole, however, the film lacks an emotional center that could have given it lasting impact.

—Tom Huntington, Managing Editor

The Lindbergh Case *by Jim Fisher. Rutgers University Press, 1987. 480 pp., b&w photos, $22.95 (hardbound).*

Five years after his 1927 solo flight across the Atlantic, Charles Lindbergh remained one of America's most revered public figures. Together with his wife Anne he had recently completed a year-long expedition to chart new air routes in the Orient. The birth of his son, Charles Jr., in June 1930 had been a national event.

But Lindbergh's renown ended up victimizing his family. On March 1, 1932, Charles Jr. was kidnapped from a second-story room of the family's retreat in Hopewell, New Jersey. Ten weeks later, after the Lindberghs had paid a $50,000 ransom, the baby's decomposed body was found in the woods nearby.

The Lindbergh Case, written by former FBI agent Jim Fisher, is a suspenseful re-creation of the case as it unfolded in the four years between the kidnapping and the execution of Bruno Richard Hauptmann, who, despite offers of clemency from the governor of New Jersey, never confessed to the crime. Fisher refutes the revisionists who claim that Hauptmann was railroaded or that his supposed accomplices were never brought to justice. "No one saw [Hauptmann] snatch the baby from his crib," concludes Fisher, now a professor of criminal justice, "and no one, save the killer, witnessed the child's death . . . . But in my opinion, based upon my understanding of Hauptmann's criminal record and personality as well as other evidence . . . , he murdered the baby in cold blood for the money."

Lindbergh's insistence on directing the ransom negotiations hindered initial efforts to nab the kidnapper. He did not allow the police to trace the kidnapper's telephone calls; he also intended, until the IRS overruled him, to keep his word that the serial numbers of the ransom bills would not be recorded. Lindbergh himself tracked down a number of leads, all of which proved false. The cruelest was a hoax perpetrated by a bankrupt Newport News, Virginia shipbuilder named John Curtis, who hoped to sell his story to the *New York Herald Tribune.* Lindbergh spent 13 days aboard Curtis' boat waiting for a rendezvous at sea with a nonexistent gang of kidnappers.

It was not until September 1934 that the trail of recorded ransom bills led the police to Hauptmann. The German-born carpenter had been unemployed since the spring of 1932, yet at the time of his arrest he was playing the stock market to the tune of $4,000. Police discovered $14,590 in ransom currency stashed in his garage.

Hauptmann's trial was a media

extravaganza that galvanized the nation; H.L. Mencken labeled it the "biggest story since the Resurrection." After 29 court sessions in which the jury heard 162 witnesses and considered 381 exhibits, Hauptmann was found guilty of first-degree murder. The incriminating evidence included Hauptmann's possession of ransom money, the similarities between his handwriting and that of the ransom notes, and the match between a floorboard in his attic and a side rail of the homemade ladder used in the kidnapping.

Critics of the case have since questioned the validity of the prosecution's evidence. Admittedly, lapses occurred: the police failed to precisely measure footprints found at the crime scene, for instance. But Fisher contends that the police conducted an investigation that "few modern law-enforcement agencies could match if the crime were committed today."

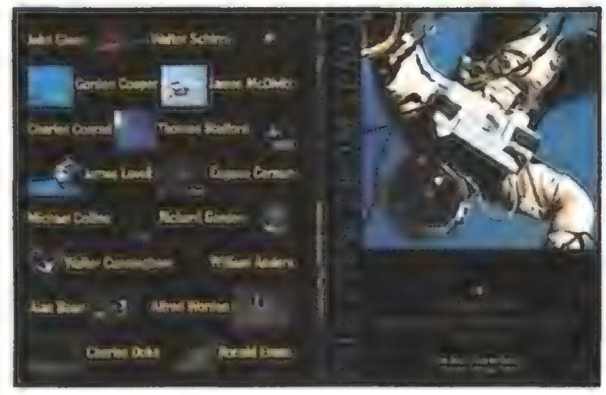
Any weaknesses in the prosecution's case were amply offset by Hauptmann's bungled defense. In the wake of several recent courtroom defeats, Hauptmann's lawyer, the bibulous but celebrated Brooklyn defense attorney Edward J. Reilly, had been nicknamed "Death House." Reilly's task was made all the less enviable by Lindbergh's impressive impact as a witness. And Reilly helped seal his client's fate, notes Fisher, by producing as alibi witnesses "a pathetic assortment of criminals, charlatans, and lunatics."

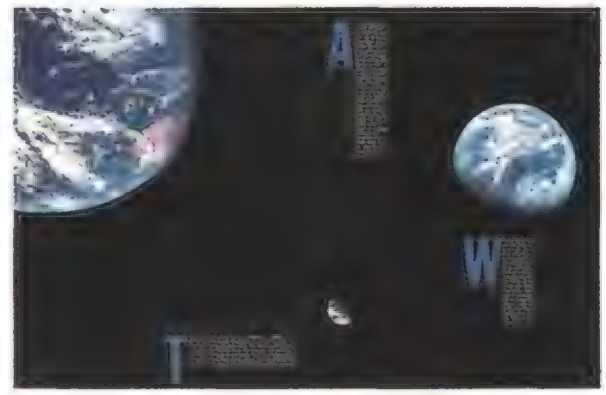
Throughout the ordeal the Lindberghs' private grief was the subject of public scrutiny. Two weeks after the baby disappeared, enterprising pilots began charging $2.50 a head to fly sightseers over the Lindbergh house; later, photographs of the baby's corpse were peddled on the street for $5 apiece. An outraged Lindbergh railed against the "publicity which we feel was in large measure responsible" for the death of his son. Partly to escape this intrusiveness, the Lindberghs and their second son, Jon, moved to Europe in 1935.

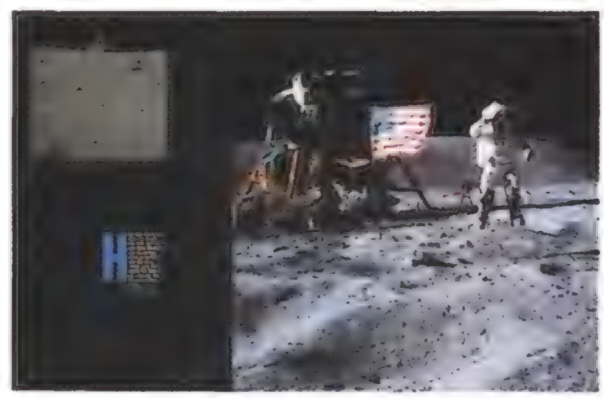
Jim Fisher's writing is far from graceful, but he uses dialogue and telling detail to great effect. Fisher justifies his practice of reconstructing certain conversations by claiming that his is the first book about the affair based on primary source materials.

Whatever the merits of Fisher's narrative technique, the continuing attention to the Lindbergh case seems to confirm the opinion of Hauptmann's assistant defense attorney: "Time," he said of the tragedy, "will never wash it away."

—Allan Fallow, an editor at Time-Life Books, has written for the "Epic of Flight" series.







The View from Space *by Ron Schick and Julia Van Haaften. Clarkson N. Potter, 1987. 128 pp., color photos, $30.00 (hardbound).*

Thumbing through *The View from Space* is like dropping in on a dozen or so "what I did on my vacation" slide shows. The difference is that these travelers journeyed into space.

The book is organized into 16 chapters, each featuring the photographs of one astronaut. Most of the text consists of the astronauts' extensive captions. Eugene Cernan explains the value of this combination, acknowledging the impact of the photographs but adding: "How did it feel for that guy to be there, to take the picture? That's another thing. The pictures alone don't do the whole job—they don't properly record the emotional or the spiritual part of the history that took place . . . ." *The View from Space* is not the first book to take on the job, but it's one of the best.

Credits

The Three Bs. Hal Higdon, a freelance writer based in Michigan City, Indiana, remains one of 40 candidates for NASA's journalist-in-space program. He is the author of a science fiction novel for children, *The Team That Played in the Space Bowl* (E.P. Dutton, 1981).

Looking for Earhart. Rear Admiral Francis D. Foley (Ret.) spent three months at sea aboard a Navy vessel at the age of 12. He is the 22nd recipient of the Gray Eagle Award, given to the Navy's senior aviator.

Sweden's 'Flying Weapon.' Steven L. Thompson is co-author of *The Wild Blue* (Crown, 1986). His article "The Big Picture" appeared in the April/May 1987 issue of *Air & Space/Smithsonian.*

Sweden's Burgeoning Space Program. David Bartal is a freelance writer who reports regularly for *U.S. News & World Report.*

Seasons, Seas, and Satellites. Frank Lowenstein is a freelance writer and a graduate student at the University of Vermont. His articles have appeared in *Technology Review* and *Sierra.*

Further reading: "Changing climate and the oceans," Woods Hole Oceanographic Institute, *Oceanus,* vol. 29, no. 4.

"The Biggest Chill," W.S. Broecker, *Natural History,* October 1987.

Get Away Special. Linda Billings is a senior editor at *Air & Space/Smithsonian.*

Further information: Get Away Special Technical Liaison, Code 740, Goddard Space Flight Center, Greenbelt, MD 20771.

The Hypersonic World of Robert Williams. Science writer T.A. Heppenheimer is the author of *The National Aerospace Plane* (Pasha Publications, 1987) as well as articles for *Omni* and *High Technology.*

Further reading: *Supersonic Cruise Technology,* F. McLean, NASA, 1985.

The Hypersonic Revolution, edited by R. Hallion, Aeronautical Systems Division, Wright-Patterson Air Force Base, 1987.

Into the Wind. Victor D. Chase is a New York-based science journalist and communications consultant who writes frequently about aviation.

Further reading: *Wind Tunnels of NASA,* D. Baals and W. Corliss, NASA, 1981.

Aeronautical Facilities Catalogue, vol. 1, NASA, 1985.

Rockets for Rain. John Hoskin is a British freelance writer based in Bangkok.

Geronimo! Fred Reed is a frequent contributor to *Air & Space/Smithsonian.*

Further information: U.S. BASE Association, 12619 S. Manor Drive, Hawthorne, CA 90250, (213) 678-0163.

BASEics, J. Boenish, American Institute of Aeronautics and Astronautics, 1986.

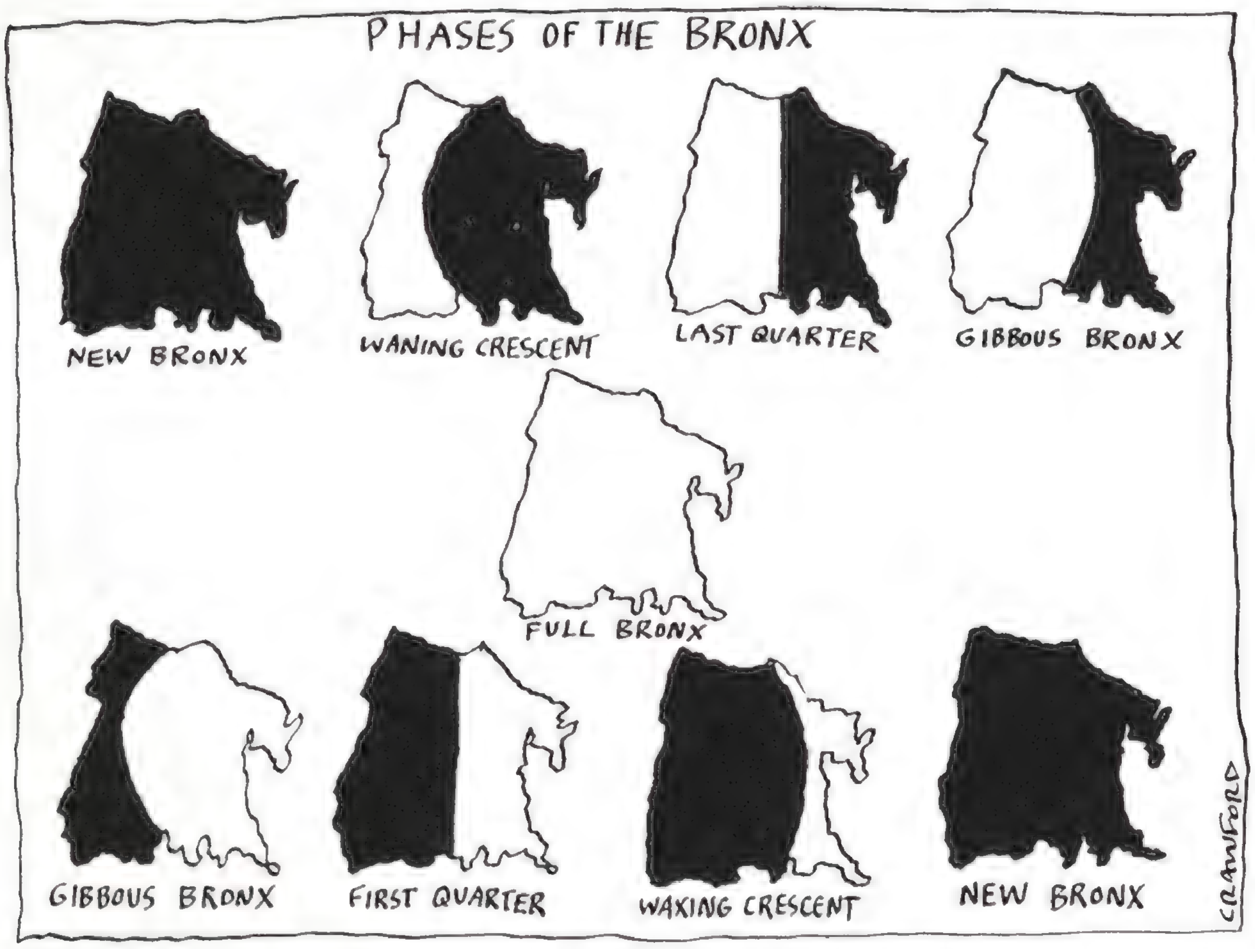
Roundup. Kevin Murphy is the Melbourne correspondent for *The Bulletin,* an Australian newsweekly magazine. His first helimustering ride was like "being on a runaway roller coaster with your eyes closed."

The Shuttle by the Bay. Katie Janssen is an associate editor at *Air & Space/ Smithsonian.*

Pushing the Button. Known as "the Old Rocketeer" to thousands of model rocketeers, science writer G. Harry Stine is the founder of the National Association of Rocketry.

Further reading: *The Rocket Team,* F. Ordway and M. Sharpe, Thomas Y. Crowell, Publishers, 1979.

NASA's Spin-Off. Bob McCafferty, a writer who lives in Fair Oaks, California, is a former television reporter who covered the aerospace industry. He admits he is old enough to remember when Chuck Yeager really did break the sound barrier—before it was popularized by the *The Right Stuff.*



"The Satellite Sky" Update/5

These regular updates to **"The Satellite Sky"** chart will enable readers to keep their charts up to date. Additions can be clipped and affixed to the chart at the appropriate altitude.

Deletions

90 to 300 MILES

Cosmos 1836 down 12-2-87	Cosmos 1886 down 11-2-87	Progress 32 down 11-19-87

Launched but not in orbit

90 to 300 MILES

Cosmos 1889 USSR photo recon	10-9-87	down 10-23-87
Cosmos 1895 USSR photo recon	11-11-87	down 11-26-87

Inoperative but still in orbit

300 to 630 MILES

NOAA 6
NOAA 7
NOAA 8
Tiros N

630 to 1,250 MILES

White Cloud
(2-5-84 version)
Cosmos 1589
Radio 3T08

6,200 to 13,700 MILES

Cosmos 1413-15
Cosmos 1490-92
Cosmos 1519-21
Cosmos 1554-56
Cosmos 1593-95
Cosmos 1650-52

21,750 to 22,370 MILES

Cosmos 1700

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7-87 TT

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Cosmos 1887
9-87 PL

Cosmos 1890
10-87 TT

Cosmos 1893
10-87 PL

Cosmos 1896
11-87 TT

Cosmos 1899
12-87 TT

Cosmos 1900
12-87 TT

Cosmos 1901
12-87 TT

KH-11
10-87 VAFB

Progress 33
11-87 TT

300 to 630 MILES

Cosmos 1891
10-87 PL

Cosmos 1892
10-87 PL

Cosmos 1898
12-87 PL

21,750 to 22,370 MILES

Cosmos 1894
10-87 TT

Cosmos 1897
11-87 TT

Early Warning
11-87 KSC

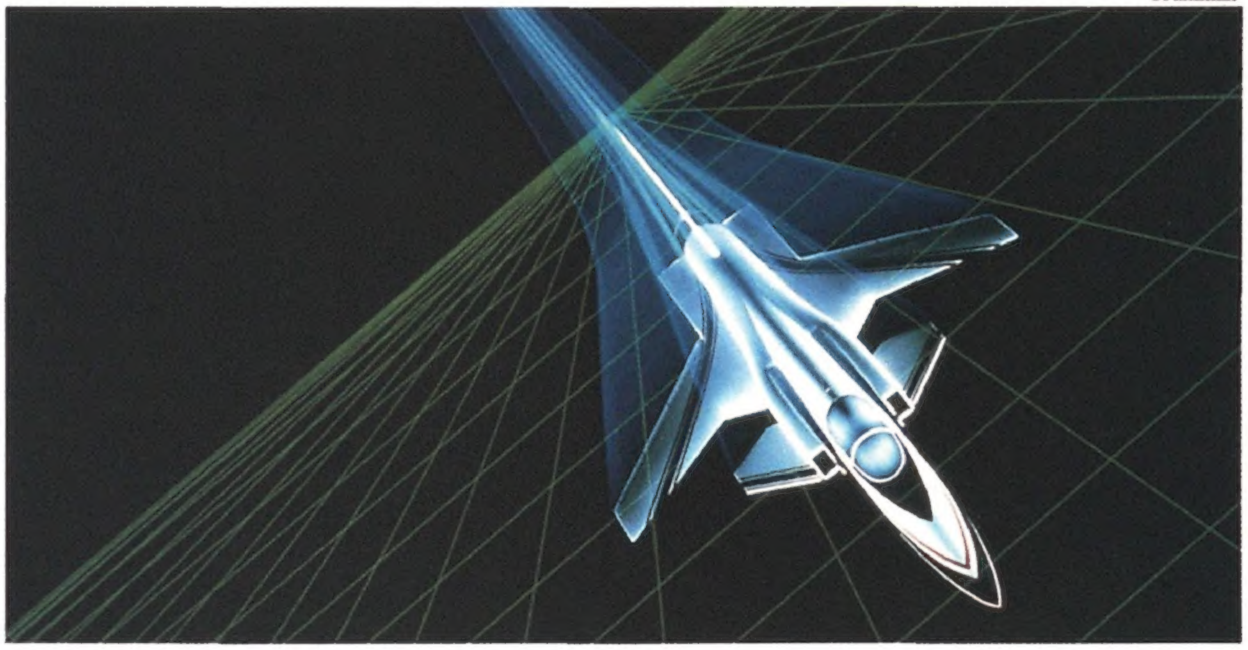
Raduga 21
12-87 TT

TV-SAT 1
11-87 KOU

Forecast

In the Wings...

Grumman



"Its wings are on backwards"—But that's not the only thing that makes Grumman's X-29 special. The United States' only working experimental airplane serves as an airborne test-bed for composites—lightweight compounds of plastics and minute strands of carbon that make up its wings. The X-29 also incorporates new technologies and designs in its canard, adjustable trailing edge, and the novel devices that help control its pitch—the strake flaps. And, thanks to a combination of wing and canard that makes it inherently unstable, this airplane may offer unparalleled agility, especially in tight maneuvers at low speeds.

Chennault Comes to Washington—In November 1940, expatriate American Claire Chennault was a colonel in the Chinese Air Force, and the Chinese Air Force was in the market for fighters. Chiang Kai-shek sent a delegation to Washington to explain the importance of protecting the Burma Road against Japanese attack and to request U.S. aid in the effort. The Curtiss P-40 was far from Chennault's first choice for a fighter, but thanks to the vagaries of politics, personalities, and production, the P-40 was what he got to equip his Flying Tigers.

Debra Schulke

A Day in the Life of a Flight Director—A satellite launch requires careful orchestration. When the Hughes Aircraft Company launches a satellite, Chief Flight Director Paul Adams helps write the score and, at launch time, plays conductor to an ensemble that spans the globe. For the launch of an Indonesian satellite, for instance, Adams and his mission control crew in Los Angeles monitored the spacecraft's launch from Kennedy Space Center (left) and supervised its deployment 22,300 miles over Indonesia.

WHAT IF THE PEOPLE WHO BUILT YOUR CAR CARED AS MUCH ABOUT IT AS YOU DO?

In the tiny town of Kalmar, Sweden—where all Volvo 760s are built—the assembly line as most people know it does not exist.

Here, people are not asked to perform small, repetitive tasks hour after hour like automatons. Instead, they work in teams assembling entire units of the car. Much of the work is done by hand. And the atmosphere resembles a workshop more than a factory.

Unlike many car workers, the "car builders" of Kalmar are rewarded not for how fast they build cars, but for how well. Here there is no anonymity. People are held responsible for their work. And they wouldn't have it any other way.

This unorthodox approach has resulted in one of the best-built automobiles in the world today: the Volvo 760.

A car you'll be proud to own. Because it's a car we're proud to have built.

VOLVO
A car you can believe in.

TODAY'S DEFENDER WEARS A DIFFERENT KIND OF ARMOR.

Modern military platforms need more than firepower to survive. Fighter aircraft must jam enemy radar to conceal their positions. Cruisers must coordinate their guns and missiles with split-second timing. Artillery batteries must use laser-guided munitions to strike with pinpoint precision.

Today's defense depends on advanced electronic systems for its success. That's why electronics is such a fast-growing part of military business opportunities, and why Lockheed has positioned itself to be a key participant in this growth.

In 1986, Lockheed's business profile included 20 different lines of business in electronics; and sales can be characterized as approximately one-third electronics and software. By 1991, Lockheed projections show more than half its revenues being derived from these vital technologies. Nearly 40% of Lockheed's engineers now work in these disciplines, and plans started in 1984 should put more than $700-million in new electronics facilities and equipment in place by 1988. The purchase of Sanders Associates in 1986 adds even more capabilities from one of the outstanding companies in the field.

On land, at sea, in the air, and now on-orbit, electronics is the new armor that gives modern military systems their winning edge. Lockheed is making sure this armor fits, no matter where the defense stands guard.

Lockheed

Giving shape to imagination.